NEC/TOKIN

CAPACITORS DATA BOOK 2005

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- All specifications in this catalog and production status of products are subject to change without notice. Prior to the purchase, please contact NEC Tokin for updated product data.
- Please request for a specification sheet for detailed product data prior to the purchase.
- Before using the product in this catalog, please read "Precautions" and other safety precautions listed in the printed version catalog.

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Correct Use of Tantalum Chip Capacitors

Be sure to read this before using NEC TOKIN Tantalum Capacitors.

[Notes]

- Be sure to read "PRECAUTIONS FOR TANTALUM CAPACITOR USE" (p56 - p66) before commencing circuit design or using the capacitor.
- Confirm the usage conditions and rated performance of the capacitor before use.
- Ninety percent of the failure that occurs in this capacitor is caused by an increase in leakage current or short-circuiting. It is therefore important to make sufficient allowances for redundant wiring in the circuit design.

[Quality Grades]

NEC TOKIN devices are classified into the following quality grades in accordance with their application. The quality grade of all devices in this document is "standard"; the devices in this document cannot be used for "special" or "specific" quality grade applications. Customers who intend to use a product or products in this document for applications other than those specified under the "standard" quality grade must contact NEC TOKIN sales representative in advance.

- Standard: This quality grade is intended for applications in which failure or malfunction of the device is highly unlikely to cause harm to persons or damage to property, or be the source of any negative effects or problems in the wider community.
- Special: This quality grade is intended for special applications that have common requirements, such specific industrial fields. Devices with a "special" quality grade are designed, manufactured, and tested using a more stringent quality assurance program than that used for "standard" grade devices. There is a high possibility that failure or malfunction of the device when being used for applications in this category will cause harm to persons or damage to property, or create negative effects or problems in the wider community.
- Specific: Devices with a "specific" quality grade are designed, manufactured, and tested using a quality assurance program that is designated by the customer or that is created in accordance with the customer's specifications. There is an extremely high possibility that failure or malfunction of the device when being used for applications in this category will cause harm to persons or damage to property, or create serious problems in the wider community. Customers who use NEC TOKIN's products for these "specific" applications must conclude an individual quality agreement and/or development agreement with NEC TOKIN. A quality assurance program designated by the customer must also be determined in advance.

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PREFACE

Thank you very much for your continuous support for and cooperation with NEC TOKIN.

Since succeeding to develop tantalum capacitors in 1955 we have continued to release leading-edge products while keeping pace with communication device development.

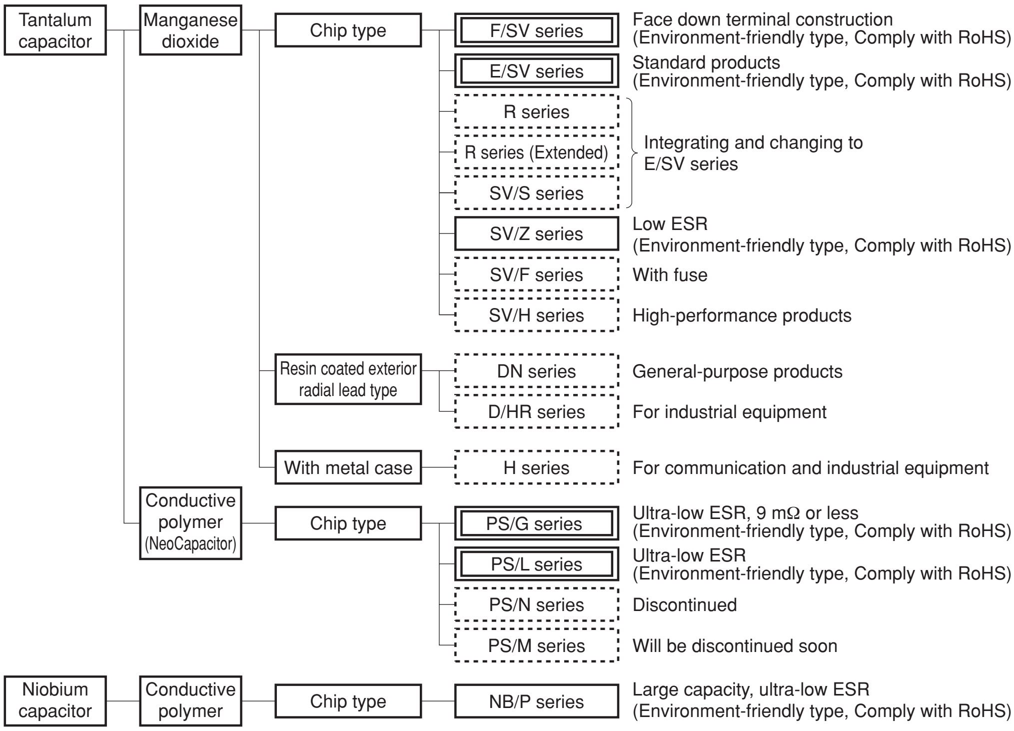
Now we are responding to customers' needs by providing a wide range of products from consumer devices (mainly mobile) to industrial devices such as measurement equipment.

For half a century, this data book–whose contents have been updated whenever necessary–has served as a "bible" of tantalum capacitors for the readers. This document is the first fully revised version in five years. We hope you to keep this document at hand whenever you use NEC TOKIN capacitors.

If you have any questions or concerns, please feel free to contact us.

March 2006

System Diagram of NEC TOKIN Electrolytic Capacitors with Solid Electrolyte



- Series enclosed in double lines are the main series.
- Series enclosed in dotted lines are included in discontinued products or non-promoted products and detailed information about them is not contained in this document.

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Products Classification Table

Type	Series	Cases										Operating Temperature Range (°C)	Rated Voltage (Vdc)	Capacitance Range (μF)	Features	Applications
		J	P	A2	A	B3	B2	C2	C	V	D					
Manganese dioxide tantalum capacitors	E/SV	○	○	○	○	○	○	○	○		○	–55 to +125	2.5 to 35	0.47 to 680	[Environment-friendly products] <1> Small size, large capacity <2> Good electrical characteristics <3> Long life <4> Rich lineup of case sizes	Bypass capacitor for: • Mobile phones • PCs and PC peripherals • Audiovisual products • Measuring instruments etc.
	F/SV	○										–55 to +125	2.5 and 4	47 and 33	<1> to <3> Same as above <4> Face down terminal	
	SV/Z				○		○		○	○	○	–55 to +125	4 to 35	6.8 to 330	<1> to <3> Same as above <4> Low ESR	• Decoupling of MPU • HDD noise absorption
Conductive polymer tantalum capacitors (NeoCapacitor)	PS/L		○	○	○	○	○		○	○	○	–55 to +105	2.5 to 16	2.2 to 1000	[Ultra-low ESR products] <1> Low impedance, low ESR <2> High permissible ripple current <3> High flame retardancy <4> Rich lineup of case sizes	• PCs and game • Mobile phones • Storage devices • Noise reduction and voltage fluctuation suppression for video camera, digital cameras, etc. • DC/DC converter smoothing
	PS/G	○									○	–55 to +105	2.5	330, 680	<1> Low impedance, low ESR of 9 mΩ or less <2>, <3> Same as above	
Conductive polymer niobium capacitor	NB/P										○	–55 to +105	2.5	220	<1> Abundance of raw materials <2> Large capacity <3> Ultra-low ES	• MPU decoupling for PCs and PDAs • High-speed image processors for game machines

(Unit: mm)

Case	EIAJ	L	W	H
J*	–	1.6 ± 0.1	0.85 ± 0.1	0.8 ± 0.1
J	–	1.6 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
P2*	–	2.0 ± 0.2	1.25 ± 0.2	0.9 ± 0.1
P	2012	2.0 ± 0.2	1.25 ± 0.2	1.1 ± 0.1
A3*	–	3.2 ± 0.2	1.6 ± 0.2	0.9 ± 0.1
A2	3216L	3.2 ± 0.2	1.6 ± 0.2	1.1 ± 0.1
A	3216	3.2 ± 0.2	1.6 ± 0.2	1.6 ± 0.2
B3	3528L	3.5 ± 0.2	2.8 ± 0.2	1.1 ± 0.1
B2	3528	3.5 ± 0.2	2.8 ± 0.2	1.9 ± 0.2
C2	–	6.0 ± 0.2	3.2 ± 0.2	1.4 ± 0.1
C	6032	6.0 ± 0.2	3.2 ± 0.2	2.5 ± 0.2
V	7343L	7.3 ± 0.2	4.3 ± 0.2	1.9 ± 0.1
D	7343	7.3 ± 0.2	4.3 ± 0.2	2.8 ± 0.2

* Applies only to F/SV series (face down terminal)

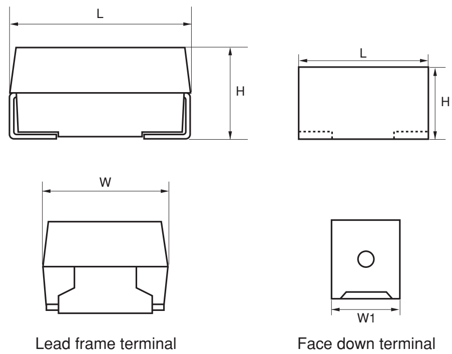

Figure 1. External View of Chip Capacitor

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OVERVIEW OF CAPACITORS

1. Basic Structure of Capacitors

Capacitors are a type of electronic component employed in various electronic devices.

A capacitor is composed of two electrodes with a dielectric (generally, an insulator) sandwiched between them. When a voltage is applied between the electrodes, the capacitor stores an electrical charge (electricity) due to dielectric polarization of the dielectric.

Unlike condensers (e.g. batteries) which use electrochemical changes, capacitors can repeatedly charge and discharge within an extremely short time. However, they cannot store as much electricity as batteries. Because of these differences, the applications of capacitors differ from those of batteries.

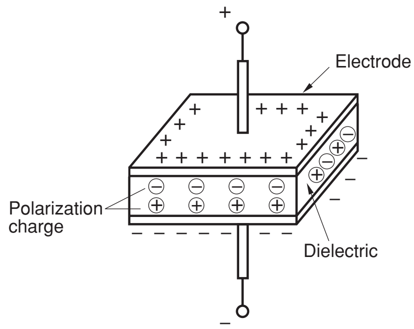

Figure 2. Basic Structure and Principle of Capacitor

2. Types and Main Features of Capacitors

The volume of capacitors manufactured in the world in 2001 (January through December) was 1.2489 trillion units (104.1 billion units per month), which amounted to 1.6632 trillion yen (138.600 billion yen per month).

Percentages of typical capacitors based on the production volume are as follows: Ceramic, 82.8%; aluminum electrolytic, 10.0%; tantalum, 2.6%; other, 4.6%.

Percentages of typical capacitors based on the monetary amount are as follows: Ceramic, 41.5%; aluminum electrolytic, 27.7%; tantalum, 13.4%; other, 17.4%.

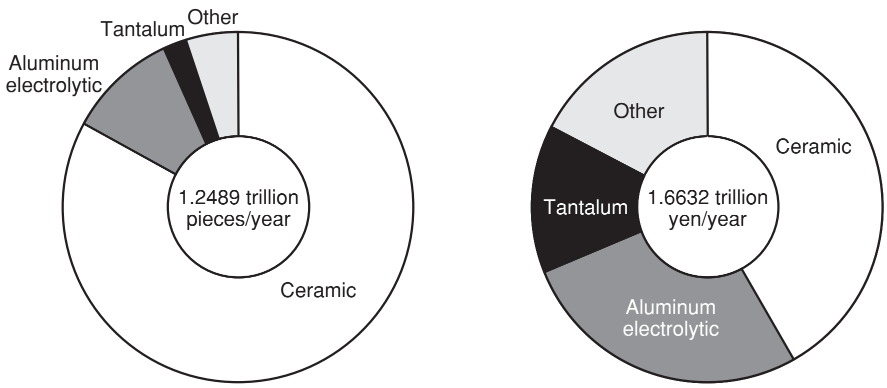

Figure 3. World Capacitor Production Totals in 2001

Source: Sangyo-Joho Limited

Table 1 shows the features of typical capacitors.

Table 1. Features of Typical Capacitors

Type / Parameter	Film	Ceramic	Tantalum	Aluminum
Dielectric	Polyester, polystyrene, polypropylene, etc.	Titanium oxide, barium titanate, lead compounds, etc.	Tantalum pentoxide (Ta_2O_5)	Aluminum trioxide (Al_2O_3)
Basic structure	Foil Metalized film	Disc Boundary-layer semiconductor Multilayer ceramic capacitor (MLCC)	Non-solid electrolyte (liquid electrolyte) Solid (inorganic solid electrolyte, conductive polymer)	Non-liquid electrolyte (jelly electrolyte) Solid (inorganic solid electrolyte) (organic solid electrolyte)
Capacitance range (approximate values)	0.5 pF to 10 μF	Disc 0.5 pF to 0.2 μF Multilayer ceramic capacitor 0.5 pF to 100 μF	0.1 to 680 μF	0.47 to 10^5 μF
Form	Resin coated exterior radial lead (dominant) Chip	Resin coated exterior radial lead Chip (dominant)	Resin coated exterior radial lead Chip (dominant)	Encased (dominant) Chip
Advantages	• Low price • Good performance	• Low price • Small size (especially MLCC) • High reliability • Low ESR (especially MLCC) • Non-polar	• Relatively large capacitance in small size • Relatively good performance • Semi-permanent life	• Low price • Large capacity
Disadvantages	• Weak against heat and chemicals • Large external dimensions	• Capacitance widely changes due to temperature or DC voltage. (High dielectric constant type)	• Must be used with attention to voltage margin • Polar	• Short life at high temperatures (except solid type) • Polar

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3. Capacitor Selection Criteria

Figure 4 shows the equivalent circuit of a capacitor.

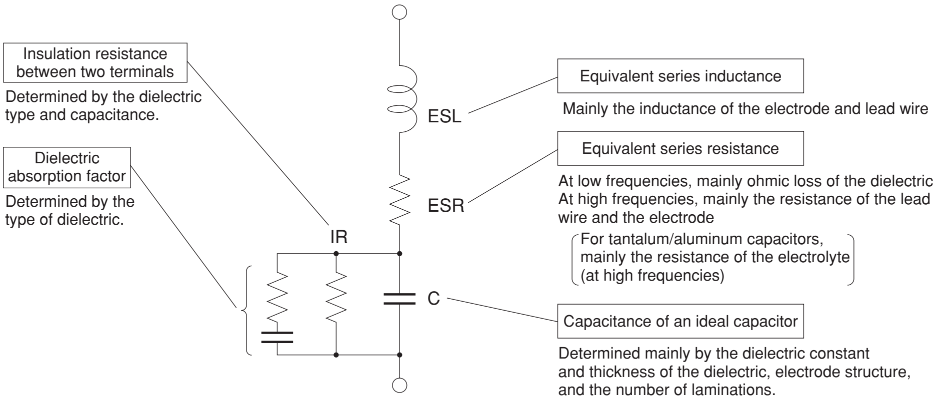


Figure 4. Equivalent Circuit of Capacitor

Capacitors should ideally be small and have a large capacitance, an infinite insulation resistance between two terminals, and an equivalent series resistance of zero. However, no capacitors satisfy all of these conditions. Each type of capacitor has advantages and disadvantages; therefore refer to "Considerations Based on Circuit" in Table 2 when designing a circuit. The contents of Table 2 are arranged according to the characteristics of each circuit, because each set has its own price, shape, and capacitance.

Table 2. Considerations Based on Circuit

Consideration / Circuit Used	Stability of C	ESL	ESR	IR	Dielectric Absorption	Optimum Capacitors
Tone control circuit	○	○	○			Film, tantalum
Smoothing circuit for power supply output		○	○			NeoCapacitor, multilayer ceramic, aluminum electrolytic
Time constant circuit	○			○	○	Film, tantalum
High frequency circuits in general		○	○			NeoCapacitor, multilayer ceramic
Coupling circuit	○	○	○			Tantalum, film, multilayer ceramic (B-characteristic)
Bypass circuit (Decoupling)		○	○			Tantalum, aluminum electrolytic, multi-layer ceramic, NeoCapacitor

A circle indicates a consideration that applies to the circuit used.

4. How to View Characteristic Data Diagrams

(Frequency characteristics)

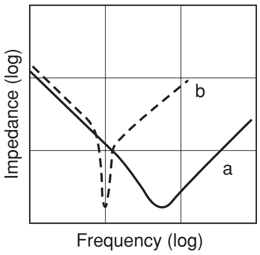


Figure 5. Impedance - Frequency Characteristics (1)

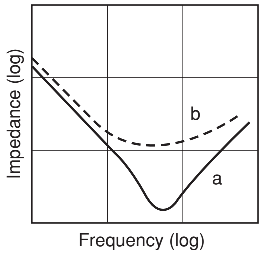


Figure 6. Impedance - Frequency Characteristics (2)

In Figure 5, if curves for the same capacitance value are a and b, which capacitor has the better impedance frequency characteristics? The answer is a. The reason is that the ESL is small for a and large for b.

Generally, the frequency characteristics of a chip type are more favorable than those of a resin coated exterior radial lead type.

In Figure 6, if curves for two types of capacitors are a and b, respectively, which capacitance has the smaller ESR? The answer is a.

The impedance value at the bottom of the curve approximates the ESR value. Capacitor types lined up in order of good frequency characteristics are as follows.

Multilayer ceramic > Film > Tantalum > Aluminum electrolytic

The ESR values of aluminum electrolytic capacitors are higher than those of other capacitors; therefore aluminum electrolytic capacitors do not function fully at high frequencies. Figure 7 shows the frequency characteristics of ESR for an aluminum electrolytic capacitor, a tantalum capacitor, and a NeoCapacitor, and Figure 8 shows their frequency characteristics of capacitance. One problem for digital circuits is the response to signal changes; the two figures show that the NeoCapacitor's response to signal changes is superior to that of other electrolytic capacitors.

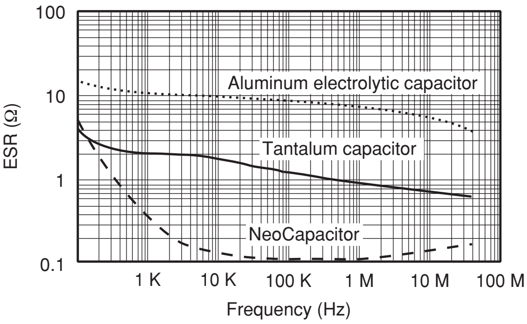


Figure 7. ESR vs. Frequency Characteristics

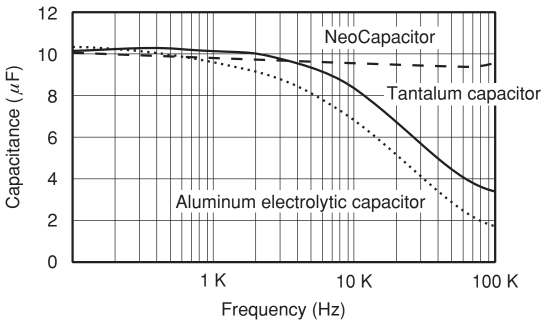


Figure 8. Capacitance vs. Frequency Characteristics

(Temperature characteristics)

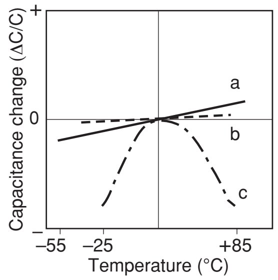


Figure 9. Capacitance vs. Temperature Characteristics

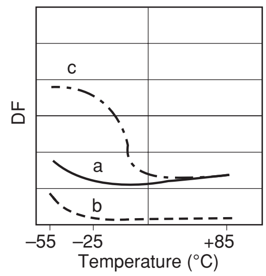


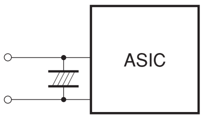
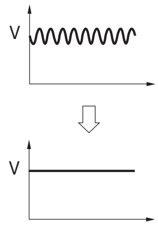
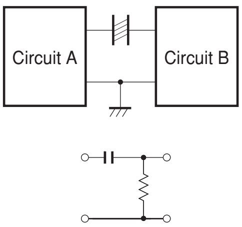
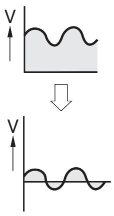
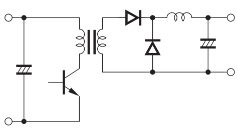
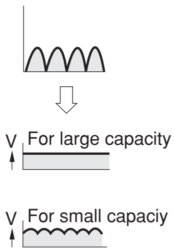
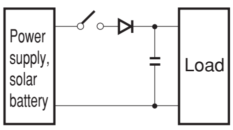
Figure 10. DF (Dissipation Factor) vs. Temperature Characteristics

See Figures 9 and 10. Which one of a, b, and c is the capacitor with the lowest dielectric absorption? The answer is b. Capacitors whose capacitance and DF are not greatly changed by temperature and whose DF value is small have low dielectric absorption; accordingly they are suitable for integrating circuits.

The patterns of b are often seen in polypropylene film capacitors or temperature compensating ceramic capacitors, the patterns of a in tantalum capacitors or polyester film capacitors, and the patterns of c in high dielectric constant ceramic capacitors.

5. Applications and Roles of Capacitors

Table 3. Applications and Roles of Capacitors

Application	Basic Circuit Example	Role of Capacitor in Circuit	Required Characteristics of Capacitor	Application Circuit (Set) Example
For bypass	Connected between power supply line and ground. * Power supply line of LSI, ASIC, etc. 	To supply a stabilized DC voltage, removes high-frequency noise that is superimposed on the power supply line due to external induction or high-speed circuit driving. High-speed noise 	• Low ESR • Comparatively large capacity • Small size desired	General electronic circuit power supply lines • Mobile phones • Personal computers • DVDs • Audio sets • Digital cameras • Video CDs • Electronic instruments • Other general electronic equipment
For coupling	Connected between front circuit (A) output and rear circuit (B) input. 	Removes DC bias voltage of front circuit and transmits AC signal voltage to rear circuit. 	• Low leakage current • Low ESR	Voice codecs • Audio sets • Mobile phones • Car navigation systems (voice) • Personal computers (voice) Voice demodulators (DA converter) • Video CDs • Game machines • Electronic instruments Equalizer amplifiers • Car stereo CCD image processing circuit • Digital cameras
For smoothing of power supply output	Connected parallel to load in output line of rectification circuit. 	Converts output waveform in power supply circuit that converts alternating current to direct current to voltage closer to direct current. 	• Large capacity • Low ESR • High resistance to ripple current	Power supply circuits • SW regulators • DC power units
For backup	Connected between load side power supply line and ground. 	At the time of instantaneous power shutdown, the capacitor provides electricity that was stored while the power supply line was normal for the load and temporarily maintains the voltage of the power supply line on the load side.	• Large capacity	Microcomputer backup

GENERAL DESCRIPTION OF TANTALUM CAPACITORS

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1. History of Development

Electrolytic capacitors with solid electrolyte are capacitors that have the following structure:

(A) An oxide film (a dielectric) is formed on the surface of a valve metal.

(B) Solid electrolytes, which serve as cathodes, are adhered to the oxide film and the metal.

Electrolytic capacitors with solid electrolyte feature the smallest external dimensions among capacitors of identical capacitance because the extremely thin oxide film (dielectric) achieves a large capacitance per unit area and the use of fine powder leads to an enlarged surface area.

Capacitors in which tantalum is used in the valve metal are tantalum electrolytic capacitors with solid electrolyte (tantalum capacitors).

In 1955, Bell Telephone Laboratory researched whether manganese dioxide could be used for electrodes to develop tantalum electrolytic capacitors with solid electrolyte; around the same time NEC TOKIN succeeded in developing tantalum electrolytic capacitors with solid electrolyte.

We released a metal case type in 1959, a low-priced resin-coated exterior radial lead type in 1970, and a chip type (the SV series) that is coated with resin mold and that supports SMT in 1981.

We have responded to diverse market needs by always aiming for "large capacity in the world's smallest form" and by putting into practice development and commercialization that are half a step ahead of the field.

As electronic equipment has been digitized and provides higher frequency and lower power consumption, the demand for low equivalent series resistance (ESR) capacitors has risen. To respond to this demand, in 1993 we succeeded in developing the NeoCapacitor whose cathode layer is composed of a conductive polymer whose internal resistance is up to 100 times lower than that of the conventional manganese dioxide. The NeoCapacitor was released in 1994.

With the increasing miniaturization and sophistication of electronic equipment and its performance, the NeoCapacitor has been gaining an excellent reputation thanks to its excellent noise absorption characteristics derived from low ESR as well as low impedance, and has shown rapid growth in the market.

In 2001, to provide capacitors with higher capacitance, we developed electrolytic capacitors with solid electrolyte that employ niobium as the main material.

We will continue releasing products that satisfy customers in a timely manner.

2. Structure and Principles

Figure 12 shows the structure of a chip tantalum capacitor.

With the anode oxidation method, tantalum oxide (Ta_2O_5) (the dielectric) is formed on the surface of the tantalum that serves as the anode and a manganese dioxide (MnO_2) layer (the electrolyte) is formed on the Ta_2O_5. A graphite layer and a metal layer are then formed on the MnO_2 layer to derive the cathode.

In the PS/L series and PS/G series of NeoCapacitor, a polyvinylene (PV) conductive polymer is used instead of MnO_2. Moreover, in a niobium capacitor, the tantalum homologous metal niobium (Nb) is employed as the anode.

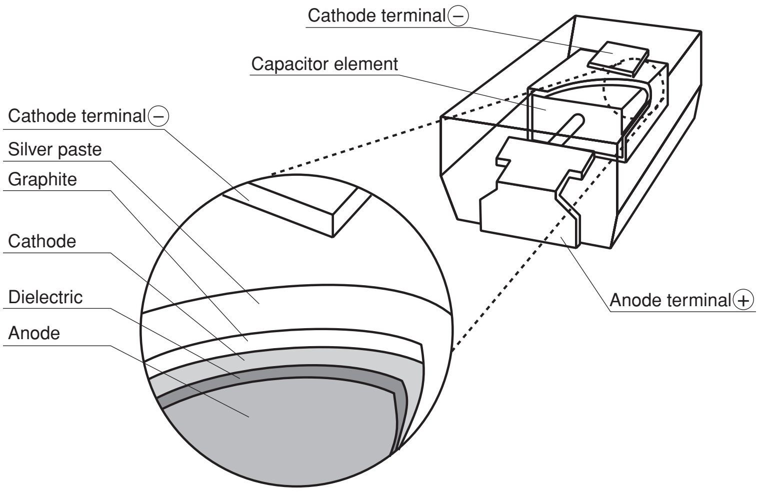

Figure 12. Structure of NEC TOKIN Chip Tantalum Capacitor

	Conventional Manganese Type		Conductive Polymer Type	
	E/SV Series F/SV Series	Not commercialized *	NeoCapacitor PS/L Series PS/G Series	NB/P Series
Cathode	Manganese dioxide	Manganese dioxide	Conductive polymer	Conductive polymer
Anode	Tantalum	Niobium	Tantalum	Niobium
Dielectric	Tantalum oxide film	Niobium oxide film	Tantalum oxide film	Niobium oxide film

* Can be developed, but there is no plan to commercialize these capacitors because the market demands low ESR.

Tantalum capacitors have rectification characteristics. However, the rectification mechanism is not well understood at present. We simply mention this here with respect to the rectification mechanism explained from the standpoint of semiconductor rectification that is being tested by H. E. Haring[1] and Ishikawa[2].

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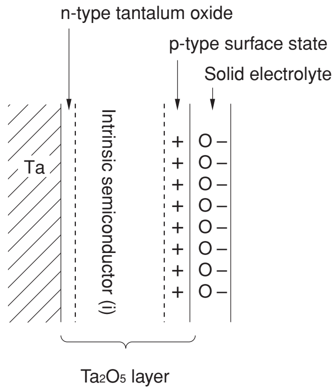

Figure 13. Semiconductor Model

As shown in Figure 13, the part adjacent to the metal side of the oxide film is an n-type tantalum oxide layer containing at least as many excessive tantalum atoms as a chemical equivalent of Ta_2O_5 and is presumed to be a layer as thin as 5 to 10 nm. The layer following that layer is regarded as an intrinsic semiconductor having a composition that is chemically equivalent to Ta_2O_5, and this layer has a thickness proportional to the anodization voltage (voltage to form an oxide film) and works as a dielectric that determines the capacitance. However, the ions adhered to the surface of the oxide film or the solid electrolyte (for example, manganese dioxide) that is stuck to the surface of the oxide film constitute the surface state, and because of this, the p-type tantalum oxide layer is formed on the surface of the oxide film. Since the fine structure of the anode oxide film can be thought as a p-i-n junction, the oxide film is thought to have rectification characteristics. Even though the oxide film the dielectric is extremely thin, it shows satisfactory insulation performance and electric strength probably because of the rectification characteristics.

3. Features

Tantalum capacitors exhibit the features shown in Table 4 because they use tantalum pentoxide (Ta_2O_5) as the dielectric and use a solid as the cathode.

Table 4. Features of Tantalum Capacitors

• Advantages		
Solid is used as the cathode	⇒	Have a long life without drying up
	⇒	Characteristics are stable
Fine tantalum powder is used	⇒	Small size and large capacity are obtained
• Disadvantages		
Dielectric (Ta_2O_5) is extremely thin	⇒	Easily shorted by stress because of low electric strength of Ta_2O_5
Dielectric has rectification characteristics	⇒	Polar

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4. Characteristics

4.1 Impedance

This section describes the conceptual structure of a tantalum capacitor. It is a sintered body composed of fine tantalum powder. On the effective surface of the anode, whose pore percentage is high, a dielectric film is formed using the anode oxidation method. The cathode is composed of MnO_2 or a conductive polymer and conducts the external electrode terminal via graphite and silver paste layers. Figure 14 shows a simplified structure.

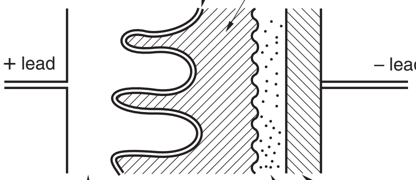

Figure 14. Diagram of Solid Tantalum Capacitor Structure

(1) Frequency characteristics

Figure 15 simply expresses a capacitor equivalent circuit in general.

Figure 15. Capacitor Equivalent Circuit

where $R_{eq\bullet s}$ = Equivalent series resistance

C = Capacitance

L = Inductance

Accordingly, the impedance Z is expressed as follows.

$$Z = \frac{1}{j\omega C} + j\omega L + R_{eq\bullet s} \quad \cdots (1) \quad (\omega = 2\pi f,\ f : \text{Frequency})$$

Since high-frequency impedance characteristics of winding capacitors, etc., are governed mainly by L (inductance), the impedance characteristics are improved by a technique such as non-inductive winding. On the other hand, such characteristics of electrolytic capacitors are mainly influenced by $R_{eq\bullet s}$. Figure 16 shows examples of these characteristics.

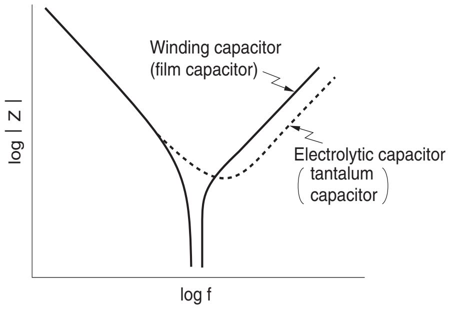

Figure 16. Capacitor Impedance Frequency Characteristics

For a sintered tantalum capacitor, $R_{eq \cdot s}$ consists of the following elements.

$R_{eq \cdot s}$
- R_f: Virtual equivalent series resistance of dielectric film calculated from $\tan\delta$ of Ta_2O_5 film itself and surface admolecules
- R_0': External series resistance except Ta_2O_5 film

R_0' is further resolved into constituent elements as follows.

R_0'
- R_0: Resistance that is related to distributed constant resistance and varies according to resistivity or porous state of MnO_2 or conductive polymer
- R_{ext}: Outer surface MnO_2 or conductive polymer/graphite/silver paste/lead terminal contact resistance and resistance of material

In other words,

$$R_{eq \cdot s} = R_f + R_0'$$
$$= R_f + R_0 + R_{ext} \qquad (2)$$

Rewriting $R_{eq \cdot s}$ as a function of the frequency (ω) yields the following expression.

$$R_{eq \cdot s}(\omega) = (\tan\delta)_f / \omega C + R_0'(\omega)$$
$$= (\tan\delta)_f / \omega C + R_0'(\omega) + R_{ext} \qquad (3)$$

This is because

$$\tan\delta = \omega C R_{eq \cdot s} = \omega C (R_f + R_0)$$
$$= (\tan\delta)_f / \omega C R_0 \qquad (4)$$

and $(\tan\delta)_f$, which is the dielectric loss determined by the nature of the dielectric film (Ta_2O_5), is nearly constant in the frequency region for use as a capacitor.

Moreover, $R_0(\omega)$, which exhibits a constant value at low frequencies, decreases to 0 at high frequencies. We will explain this phenomenon in further detail.

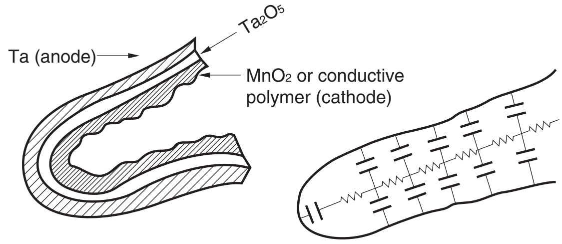

Figure 17. Model of Gap of the Sintered Anode

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The gap of the sintered anode can be represented by a C and R equivalent circuit as in Figure 17, and the frequency characteristics of the distributed constant circuit for columnar sintered tantalum in the low frequency region is represented by

$$R_0(\omega) = R_{00}\ (\text{const}) \qquad (5)$$

and in the high frequency region by

$$R_0(\omega) = \left(\frac{R_{00}}{\omega C_f}\right)^{1/2} \left(1 + \frac{\tan\delta_f}{2}\right) \qquad (6)$$

where, C_f: the capacitance in the low frequency region (const) and $\tan\delta_f$: $\tan\delta$ of the dielectric film rapidly decrease as the frequency increases over a certain frequency.

This means that $|Z|$ in the high frequency region is mainly determined by the resistance values of the outer surface, and that the internal distributed constant resistance R_0 is not included in the resistance of the MnO_2 or conductive polymer.

From the above, the $R_{eq \cdot s}$ frequency characteristics can be represented conceptually as shown in Figure 18.

On the other hand, Figure 19 shows that the capacitance also decreases drastically at 100 kHz.

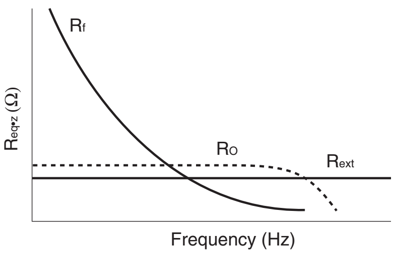

Figure 18. $R_{eq \cdot s}$ Frequency Characteristic

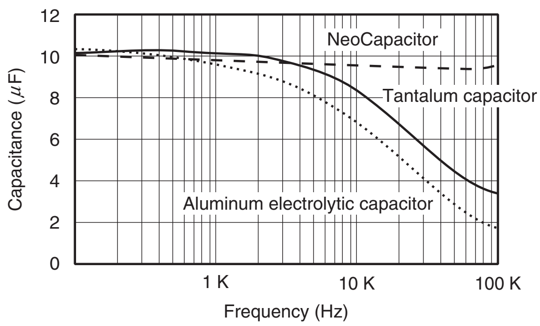

Figure 19. Capacitance vs. Frequency Characteristics

Electrolytic capacitors are C- and R-distributed constant circuits because their opposing electrodes have resistance.

Their apparent capacitance decreases as frequency increases.

Since the resistance of the conductive polymer is relatively small, the NeoCapacitor indicates that it can maintain a capacitance value up to a frequency one digit higher in relation to the tantalum (MnO_2) and aluminum electrolytic capacitors.

(2) Characteristic change due to temperature

Figure 20 shows an example of the temperature dependency of ESR. In Figure 21, the horizontal axis in Figure 20 is converted to 1/T. You can recognize that in Figure 21, which indicates semiconductor characteristics, capacitors with a high ESR value (when the capacitance is small and the rated voltage is low) lead to the formation of straight lines.

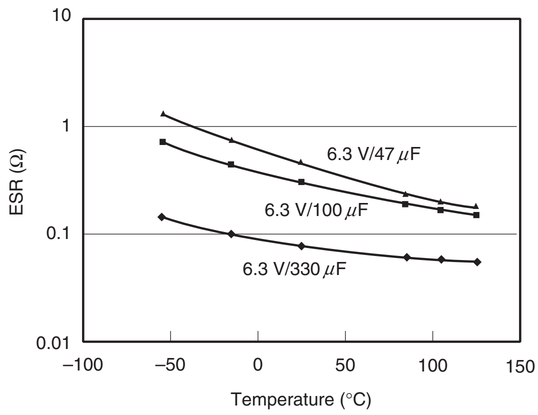

Figure 20. ESR Characteristic Change due to Temperature

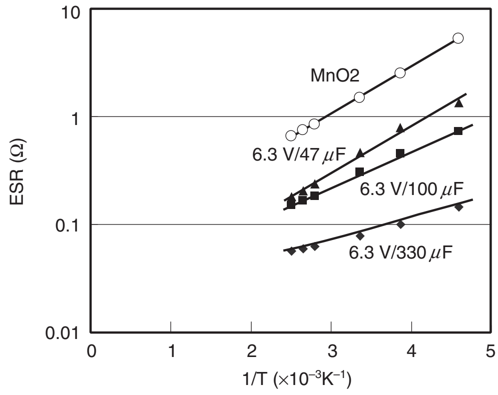

Figure 21. ESR Characteristic Change due to Temperature

For the sake of comparison, Figure 21 shows the temperature characteristics of MnO_2. The slope is nearly the same as that derived from the capacitor with the highest ESR; therefore it can be said that MnO_2 is the main cause of the temperature dependency of ESR.

Conversely, the capacitor with lower ESR (the capacitor whose CV value is large) shows more obtuse line, which leads to a presumption that ESR with low temperature dependency takes up a large share of the ESR configuration.

This phenomenon can be explained by the following physical characteristics.

The composition of $R_{eq\bullet s}$ was shown in the previous section, and here we look at its constituent elements from the standpoint of temperature dependency.

As shown on page 20, $R_{eq\bullet s} = R_f + R_0'$.

here, $R_0' = R_0 + R_{ext}$, and if we rewrite this considering temperature dependency,

$R_0' = R_0 + R_{ext}$

$= R_0 + R_1 + R_2$

where R_0 represents the internal MnO_2 resistance component, R_1 the external MnO_2 resistance component, and R_2 the resistance components other than MnO_2.

Since $R_0 + R_1$ = RMnO2 due to the fact that it is MnO_2, this becomes

$R_0' = R_{MnO_2} + R_2$

$= R_{MnO_2} + R_{Metal}$

here, the change in characteristics due to temperature for MnO_2 is expressed by the following expression due to the fact that it is also a semiconductor that does not vary internally and externally.

$R_{MnO_2} + K_{MnO_2} \exp (E/kT)$ (8)

where E: MnO_2 activation energy (eV)

T: Absolute temperature (°K)

k: Boltzmann's constant

K_{MnO_2}: Constant

In contrast, since R_{Metal} can be set as a function R_{Metal} (T) having positive temperature characteristics with respect to temperature changes,

$$R_0' (T) = K_{MnO_2} \exp (E/kT) + R_{Metal} (T) \qquad (9)$$

In other words, MnO_2 has show negative characteristics with respect to temperature changes, and the resistance components other than MnO_2 show positive characteristics with respect to temperature changes. Accordingly, by measuring the change in characteristics due to the temperature of R_0, it is possible to decide whether R_{MnO_2} or R_{Metal} is in control.

This is illustrated in Figure 22.

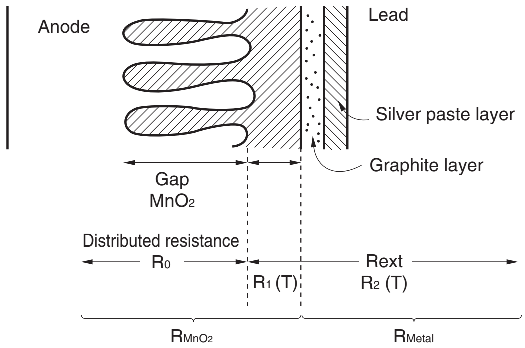

Figure 22. R_{MnO_2} and R_{Metal} Partition Diagram

Instead of using the aforementioned MnO_2, the NeoCapacitor uses a conductive polymer with excellent temperature characteristics. Accordingly, the characteristics of the NeoCapacitor gently change in relation to temperatures. As shown in Figure 23, the temperature characteristics curve of conductive polymer indicates that the characteristics gently change according to change in temperature. The activation energy is 0.015 eV, which is about one fifth as large as that of tantalum (MnO_2). Particularly, the conductive polymer shows few characteristic changes at 0°C or lower.

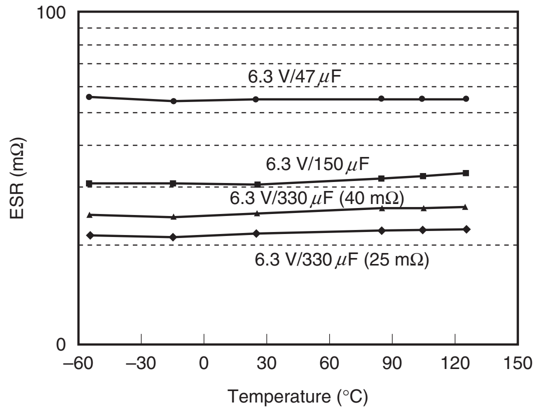

Figure 23. ESR Characteristic Change Due to Temperature

4.2 DC Current Flowing in Capacitors

(1) Composition of DC current

In general, current flowing into electrolytic capacitors in which an oxide film is used as the dielectric is classified into the following three kinds.

(a) Dielectric absorption current (I_D)
(b) Intrinsic leakage current (I_L)
(c) Surface leakage current (I_R)

The dielectric absorption current, which is derived from polarizing of the dielectric material, is a current that decreases over time and ultimately becomes 0. This current may cause problems in timers or other circuits that use the CR constant because although the current flows only for a short time, it is comparatively large.

The intrinsic leakage current is the normal current that flows through the dielectric and affects reliability.

The surface leakage current is the current that flows through the side path of the dielectric and that is affected by moisture absorption and dirt. This current may become unstable depending on the atmosphere in which the capacitor is placed.

(2) Change of DC current over time

Figure 24 shows an example of the change of DC current over time. Curve 1: Electrical characteristics of a capacitor whose leakage current is relatively large

Curve 2: Electrical characteristics of a capacitor whose leakage current is in-between

Curves 3 and 4: Electrical characteristics of capacitors whose leakage current is low

Each curve shows similar characteristics: It decreases in a constant slope until a certain time elapses and then becomes a flat line at a certain current value. (According to circumstances, it may increase or decrease due to the thermal degradation or restoration effect of the dielectric.)

This phenomenon can be shown by the sum of the dielectric absorption current, in which the DC current decreases in a constant slope, and the leakage current that is a constant value from the beginning.

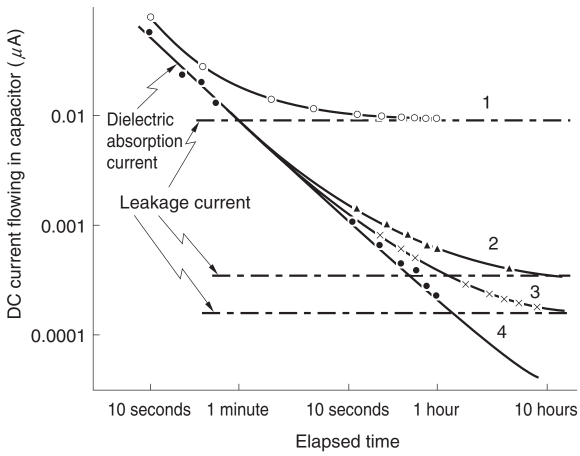

Figure 24. Change of DC Current Over Time

The dielectric absorption current generally can be expressed in the following form.

$I_D = CV\psi(t)$ (10)

where C: Capacitance
V: Applied voltage
$\psi(t)$: After-effect function (determined only by physical nature of the dielectric)

In the case of a solid dielectric, it has been confirmed experimentally that $\psi(t)$ can be expressed in the form of the following expression (provided t > 10 seconds).

$$\psi(t) = AT^{-n} \qquad (11)$$

For a tantalum capacitor, n is in the range of 0.85 to 1.0, which satisfies the relationship in expression (10).

(3) Current voltage characteristics

As shown in expression (10), the dielectric absorption current (I_D) immediately after voltage application increases proportionally to the applied voltage but the leakage current (I_L) becomes dominant as time elapses. In general, since the leakage current causes problems when used at a normal bias voltage, the current voltage characteristics of the leakage current (I_L) are described here.

Figure 25 shows an example of the voltage characteristics of a leakage current (I_L). The relationship $\log I_L \propto \sqrt{V}$ holds over a wide range of applied voltages. If the horizontal axis is expressed in rated voltage (U_R) ratios, the slope of the graph is nearly constant.

Depending on the surface state of the oxide film, current with a space-charge limited form of current may also be observed, and the relationship $I_L \propto V^2$ remains.

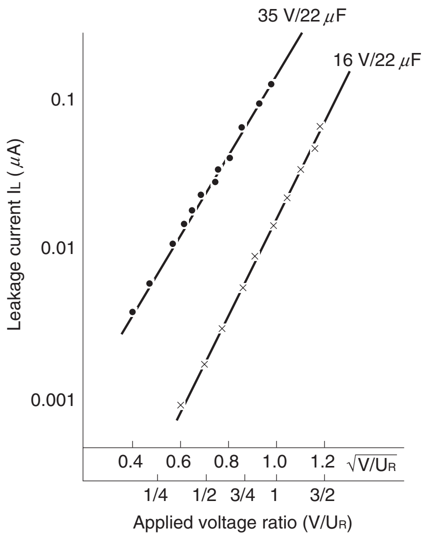

Figure 25. Voltage Characteristics of Leakage Current

(4) Capacitors' CV values and leakage current

In general, the DC current that flows when the rated voltage is applied to a capacitor is proportional to the CV value (the product of the capacitance and rated voltage) of the capacitor, and this value is distributed over the range of 0.02 CV [nA] to 0.01 CV [μA] (value 5 minutes after application). Since the lower bound is determined by the dielectric absorption current, it varies according to the measurement time.

Figure 26 shows an example of capacitor CV values and leakage currents. The relationship described above holds because the CV value is proportional to the anode effective surface area. In other words,

$$C = \varepsilon_s \varepsilon_0 \frac{S}{d} \qquad (12)$$

Where C: Capacitance

ε_s: Dielectric constant of tantalum oxide film (approx. 27)

ε_0: Vacuum dielectric constant (8.854×10^{-12} F/m)

d: Thickness of tantalum oxide film

S: Anode effective surface area

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The thickness of the oxide film (d) has the following relationship.

$d = \alpha_0 V_f = \alpha_1 U_R$ (13)

Where α_0, α_1: Constants

V_f: Oxide film formation voltage (anodization voltage)

U_R: Rated voltage

Accordingly, from expressions (12) and (13),

$$C = \varepsilon_s \varepsilon_0 \frac{S}{d}$$

$$= \varepsilon_s \varepsilon_0 \frac{S}{\alpha_1 U_R}$$

$$\bullet\ CU_R = \varepsilon_s \varepsilon_0 \frac{S}{\alpha_1} \quad (14)$$

$$\therefore CU_R \propto S \quad (15)$$

and you can see that the CV value is proportional to the anode effective surface area (S).

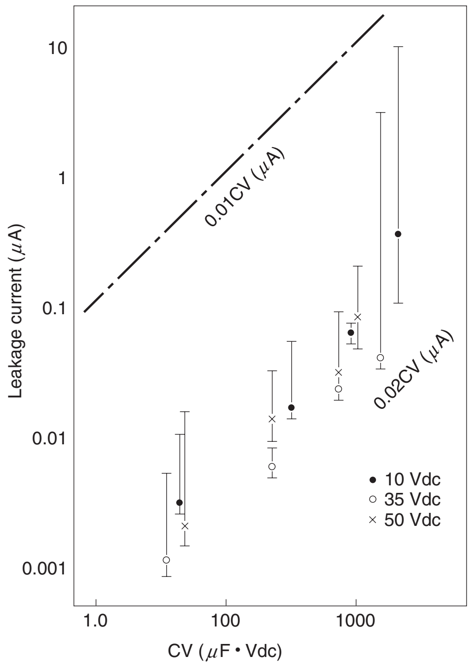
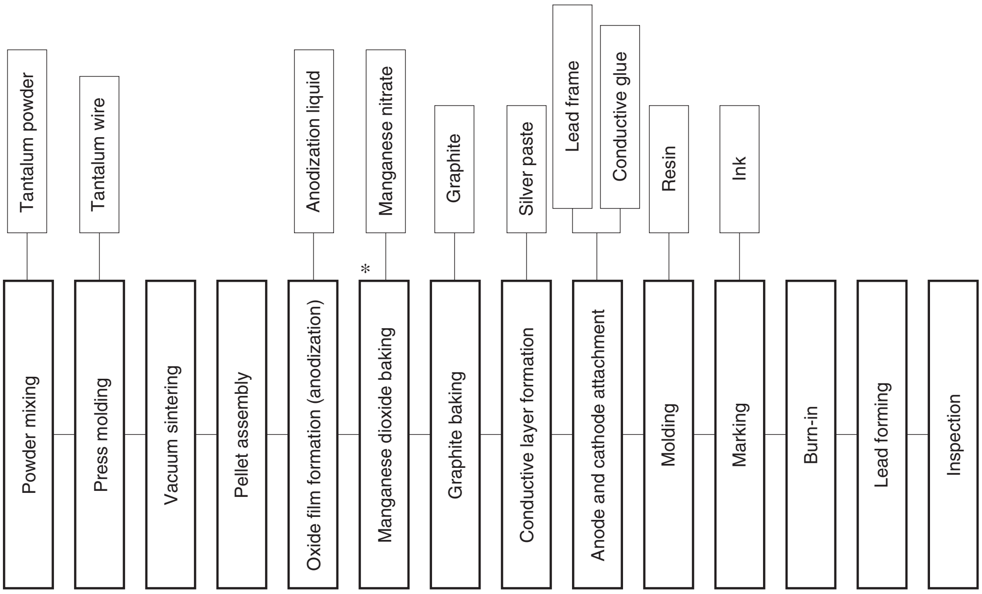


Figure 26. Relationship Between Capacitor's CV Value (CU_R) and Leakage Current

5. Manufacturing Process

The manufacturing process of a tantalum capacitor is explained according to a manufacturing block diagram (Figure 27). This is an example of a resin mold coated chip type tantalum capacitor. By molding tantalum powder to a density of 4 to 9 and sintering this in a vacuum at a temperature of 1300 to 2000°C, sintered tantalum (a pellet) with a porosity of 30 to 70% is obtained. A tantalum oxide film is formed electrochemically on the surface of the particles of sintered tantalum. The tantalum oxide film is dielectrics.



* For a NeoCapacitor, this block is "Polymerization of the conductive polymer".

Figure 27. Manufacturing Process Block Diagram

Next, a manganese nitrate solution is infiltrated into the holes of the element that formed the oxide film. Then, the element is heated and decomposed in an atmosphere in which the temperature is 200°C to 400°C so that a manganese oxide layer, the cathode, covers and fills the microscopic holes on the surface of the electrode. This process is repeated several times so that a fine layer of manganese dioxide is formed.

At this time, anodization (forming a dielectric film) is performed again at a voltage that is 2 to 3 times higher than the rated voltage to restore the oxide film that was exposed to thermal stress. A graphite layer is also formed on top of the oxide film to complete the bond, and a metal layer is further formed on top of the graphite layer. To form a metal layer that will lead to easy production of the cathode, the graphite layer is immersed in a silver paste solution and dried as well as solidified. At this point, capacitor characteristics can be obtained.

Various coatings are provided for tantalum capacitors depending on the required mountability and environmental resistivity. In the case of chip tantalum capacitors, the outer resin is coated by molding. After going through marking, burn-in, lead forming, and inspection processes, tantalum capacitors are attached to carrier tape and packed. Finally, they are delivered to the market.

A NeoCapacitor is formed by polymerizing a conductive polymer instead of the previously described manganese dioxide.

6. Organization of QC and QA Systems

6.1 QC and QA Systems

NEC TOKIN capacitors have obtained ISO9001 and QS9000 (quality control standard jointly promulgated by the big three of the American automotive industry–Daimler-Chrysler, Ford, and General Motors) international standards qualification.

At every site (manufacturing base), a "quality policy" is established and CS•Q (customer satisfaction and quality) objectives for realizing the quality policy are defined. We strive to improve the QC and QA systems by expanding the policy to each department.

The QC and QA systems ensure "the provision of products that satisfy customers" by setting the following contents in regulations and conducting internal quality audits and management reviews to promote review and improvement of the quality system.

[Organization of QC and QA systems]

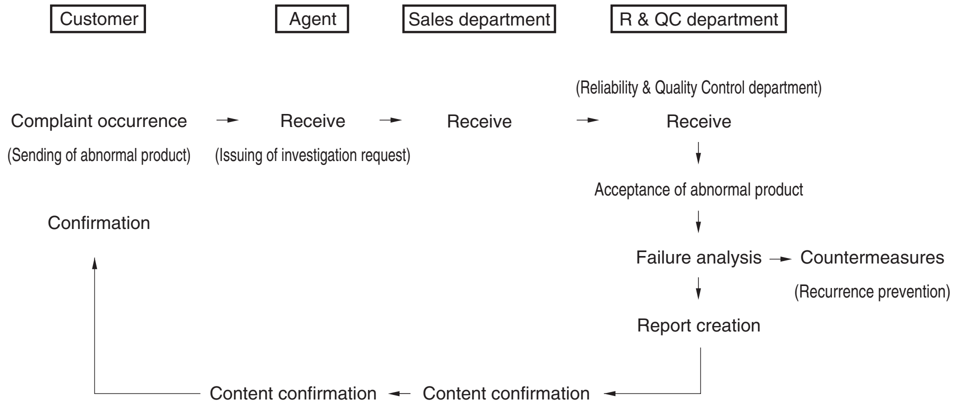
<1> Quality policy
<2> Application of quality policy (management of objectives)
<3> Document control system
<4> Process control system
<5> Quality qualification system
<6> Abnormality control system
<7> Customer complaint processing system
<8> Training & practice

6.2 Regular Quality Assurance Tests

The reliability of tantalum capacitors is determined by the product design, the quality of raw materials, and the manufacturing process. Reliability is maintained at each of these stages by design review, quality engineering, raw material ingredient confirmation, process quality control, 100% burn-in, and 100% inspection. Furthermore, we execute regular quality assurance tests for finished products and check their reliability. (See 7.3 for the contents of reliability checking.)

6.3 Response to Customer Complaints

The complaint response procedure shown in Figure 28 has been established in order to respond to customer complaints rapidly when they occur.



Notes 1: For urgent response, the abnormal product can also be sent directly to the R & QC department.
2: See the end of this document for contacts.

Figure 28. Complaint Response Procedure

7. Reliability and Quality Control

As electronic equipment has become more sophisticated and reliable, extremely high reliability is now required for the electronic components used in the electronic equipment. In order for NEC TOKIN tantalum capacitors to respond to such market demands, we strive to guarantee high reliability by improving the reliability design and executing appropriate manufacturing process quality control.

7.1 About Reliability Design

To promote optimum design that ranges from the selection of materials to the consideration of usage conditions, NEC TOKIN employs the quality engineering when designing.

The following are the most important design elements controlling the reliability and quality of tantalum capacitors.

(1) Structure design

Optimal design suited to customer needs such as external dimensions, coating materials (including reliability of material), is being executed.

(2) Product design

(a) Tantalum powder purity, particle size, and CV value

Impurities (e.g. sodium and potassium) contained in the tantalum anode are the cause of non-uniform dielectric oxide film ($Ta2O_5$), which has a negative effect on leakage current characteristics. In addition, variations in particle size and CV values are the cause of variations in capacitance and the dissipation factor (DF).

Accordingly, reliability is raised by using a tantalum powder that is at least 99.99% pure, performing vacuum sintering at one thousand several hundred to two thousand degrees centigrade, and removing impurities (Fe, Cu, Ni, and so on).

(b) Uniformity of dielectric oxide film (Ta_2O_5)

The uniformity of the oxide film (Ta_2O_5) that is the dielectric of the tantalum capacitor directly affects reliability.

Although the oxide film is electrochemically created (normally called anodization), uniformity of the oxide film is obtained by striving to optimize the anodization voltage, time, and liquid.

(c) Uniformity of solid electrolyte

- Manganese type ··· Uniformity of manganese dioxide (MnO_2)
  The manganese type of solid electrolyte is formed by the deposition of manganese dioxide (MnO_2) which is achieved by the pyrolyzing of manganese nitrate ($Mn(No_3)_2$).
  Optimizing the thermal decomposition temperature, time, and speed forms a uniform solid electrolyte.
- Conductive polymer type ··· Uniformity of conductive polymer
  A NeoCapacitor in which a conductive polymer is the solid electrolyte is formed uniformly by a proprietary formation technique of NEC TOKIN. The formation conditions are strictly controlled in each facility.

(d) Anode and cathode lead terminal connection

- For the anode lead terminal, a solderable lead terminal is welded to a tantalum wire planted in the tantalum capacitor element. If the weld is incomplete, it may result in an open defect or the occurrence of noise.
  Accordingly, high reliability is guaranteed by controlling welding conditions before the welding process and checking by 100% monitoring during the process.
- For the cathode lead terminal, since it is not possible to directly weld or solder a solid electrolyte (MnO_2 or conductive polymer), it is connected to the cathode lead terminal via silver paste or another conductive material. If this connection is incomplete, it is a cause of complaints of equivalent series resistance (ESR) increases, dissipation factor (DF) increases, and noise occurrence.
  Accordingly, reliability of the connection is guaranteed by controlling the dielectric material and cathode connection process (strength check).

(e) Burn-in and characteristic inspection

Burn-in is executed 100% with the aim of stabilizing product characteristics and removing products with shorts. This makes it possible to obtain initial characteristic stabilization and high reliability.

The main characteristics that are demanded in tantalum capacitors are capacitance, dissipation factor (DF), leakage current, and equivalent series resistance (ESR). NEC TOKIN ships after executing 100% characteristic inspection to meet customer requirements.

(f) Packing technique

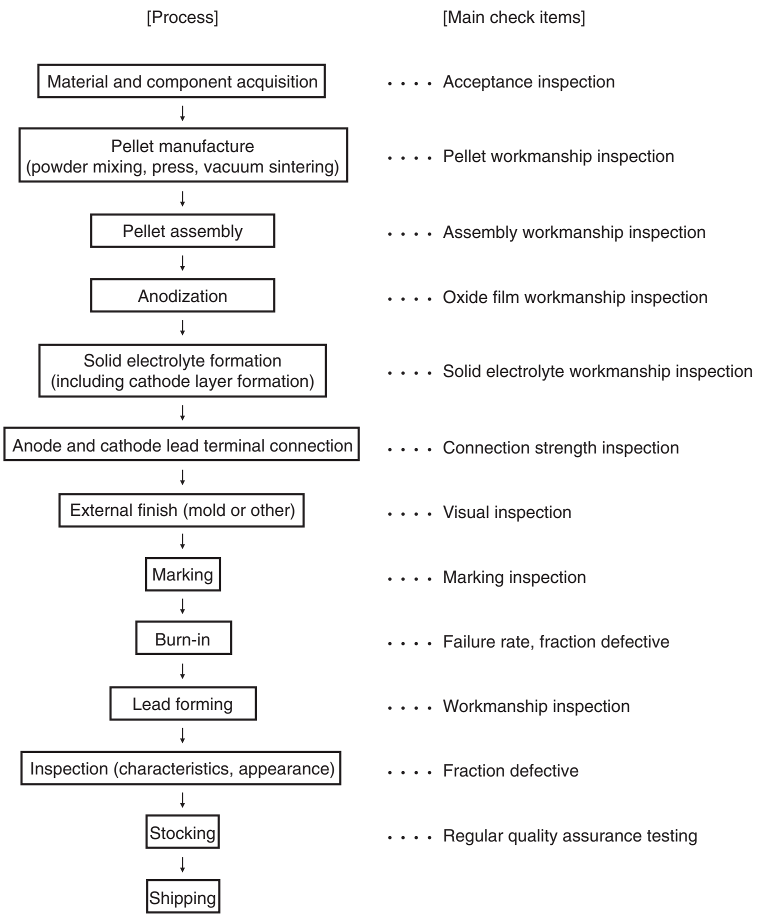
The packing techniques for tantalum capacitors are taping and bulk (bagged). Packing is designed so that customer mounting (auto mounting) is guaranteed. In addition, packing materials that are sufficiently resistant to handling and shocks during transportation are used. We will continuously improve packing materials and methods to contribute to environmental preservation.

7.2 Quality Control Systems

High-reliability tantalum capacitors can be realized by executing reliable process quality control at the design, raw material and component procurement, manufacturing, inspection, and shipping stages. Particularly in the manufacturing process, we use manufacturing process flowcharts to clarify work specifications at each process, determine check items and frequencies, and realize a system for preventing the occurrence and distribution of defects.

In addition, for purchased products such as materials and components, process quality is stabilized by performing supplier factory approvals, regular factory audits, acceptance inspections, and regular evaluations.

Figure 29 shows the tantalum capacitor manufacturing process flowchart (summary).



Note: The flow may change due to process improvement. (This is a typical example.)

Figure 29. Manufacturing Process Flowchart

7.3 Reliability Checking

The following are executed regularly as checks of tantalum capacitor reliability.

(a) Endurance test

(b) Mechanical strength and environmental tests

(c) Check of failure rate through accelerated condition tests

(d) Investigation of field failure rate

(1) Endurance test

Endurance tests are executed by continuously applying the rated voltage at the maximum rated temperature. The temperature and voltage are the main elements controlling failure modes, and it is necessary to choose test conditions that coincide with the failure modes of field use conditions. If endurance tests are executed under conditions in which the values of the test temperature or voltage are higher than the permissible values, correspondence with field failure may not be obtained, so appropriate care is needed.

Table 5 shows an overview of endurance tests performed by NEC TOKIN.

Table 5. Endurance Test Conditions

Test Method	Ambient Temperature	Rated Voltage	Test Time	Circuit Resistance	Criteria		
					Capacitance Change	DF and LC	Failure Rate
IEC 60384-11987 as per 4.23	85±2°C	Rated voltage	2000 hours	Power supply impedance: 3 Ω	Within ±10% after storing in the standard atmosphere conditions for 1 to 2 hours	DF: Shall not exceed the initial requirements LC: Shall not exceed 125% of the initial requirements	Must satisfy design failure rate level (CL 60%)
	125±2°C	Derated voltage [Rated voltage times 0.63]	2000 hours	Power supply impedance: 3 Ω	Within ±10% after storing in the standard atmosphere conditions for 1 to 2 hours	DF: Shall not exceed the initial requirements LC: Shall not exceed 125% of the initial requirements	

(2) Mechanical strength and environmental tests

The diverse usage environments of electronic components cannot be satisfied by a test that is performed uniformly. Therefore, the range of electronic components usage must be clearly understood. At NEC TOKIN, various tests for mechanical and thermal stress are executed.

For tantalum capacitors, the MIL-STD-202 test method was formerly performed, but following IEC standard introduction, IEC 60384-1 and JIS C 5101-1 have recently become core test methods (Table 6).

(3) Check of failure rate due to accelerated life test

Since the reliability of components may vary depending on the manufactured lot, we carry out regular reliability tests, in which test conditions are accelerated, for tantalum capacitors according to manufactured lot units to check the quality level.

The test conditions are as follows.

Ambient temperature: 85°C
Test circuit resistance: 3 Ω or less
Applied voltage: Accelerated voltage

Table 7 and Figure 30 show the relationship between voltage stress and the acceleration factor.

Figure 31 shows an example of the failure rate data of various tantalum capacitors.

(4) Investigation of field failure rate

Thanks to a claim feedback system, failures that occur in the field are caught and failure rates in the field are always monitored.

By always mapping failure rates to evaluation test data, we can pursue higher reliability. As an example of field failure rates of tantalum capacitors, Figure 32 shows the case of a metal case hermetically sealed type used in a certain device.

Figure 33 shows an example of the pattern of failure occurrence of a tantalum capacitor in the field (it is an actual example of a tantalum capacitor used in a certain transmission device). You can see that the MTBF gradually becomes longer as time elapses.

Because of this fact, field reliability has a close relationship with the length of time of burn-in in the capacitor manufacturing process. If particularly high reliability is demanded, a long burn-in time must be set.

Table 6. Mechanical (Physical) Strength and Environmental Resistivity Test Methods and Conditions

Test Item	Test Method	Test Conditions
Shock	JIS C 0041	Drop 3 times in 6 directions, 100G (saw wave)
Vibration	JIS C 0040	10 to 55 Hz amplitude, type A, 6 hours
		10 to 2000 Hz amplitude, type C, 6 hours
Temperature cycle	JIS C 0025 (Test Na)	–55 to +125°C, 5 cycles
Salt mist	JIS C 0023	5%$NaCL_{sol.}$ 0.3 to 0.5 ml/h, 48h
Solderability	JIS C 0054	215 ± 3°C, 3 ± 0.3 sec, immersion speed 20 mm/sec to 25 mm/sec
Resistance to soldering heat	JIS C 0050(Test Tb)	260 ± 5°C, 10 ± 1 sec, depth at least 2 mm from solder surface
Resistance to solvents	JIS C 0052	20 to 25°C, isopropyl alcohol, 30 sec. immersion
Damp heat (I)	JIS C 0022	40°C, 90 to 95% RH/60°C, 90 to 95% RH
Damp heat (II)	JIS C 0028	Include –10 to +65°C temperature cycle, max. 96% RH, 10 cycles
Terminal strength	JIS C 0051 (Test Ua_1)	Pull strength 5 to 10 N 10 sec
Terminal strength	JIS C 0051 (Test Ub)	Bending strength Weight of mass 0.25 to 0.5 kg, 90 degrees/3 sec, 2 cycles
Terminal strength	JIS C 0051 (Test Uc)	Torsion strength Severity 1 (360°, 3 times)
Bond strength of face plating	JIS C 5101-1 (As per 4.35)	Deflection 1 mm, Pressure jig R: 230
Characteristics at high and low temperature	JIS C 5101-1 (As per 4.24)	–55 to +125°C (or 85°C) Static method
Surge	JIS C 5101-1 (As per 4.26	85°C, $U_R \times 1.3$ 30 sec ON/5.5 min OFF 1000 cycles, 1 kΩ
Charge-discharge cycle	JIS C 5101-1 (As per 4.27)	Room temperature, $U_R \times 1$ 0.5 sec ON/0.5 sec OFF 10000 cycles

Table 7. Relationship between Voltage Stress and Acceleration Factor of Tantalum Capacitor

(Temperature 85°C)

Acceleration Factor	Applied Voltage/Rated Voltage
1	1.00
10	1.16
100	1.32
1 000	1.48
10 000	1.63
100 000	1.79

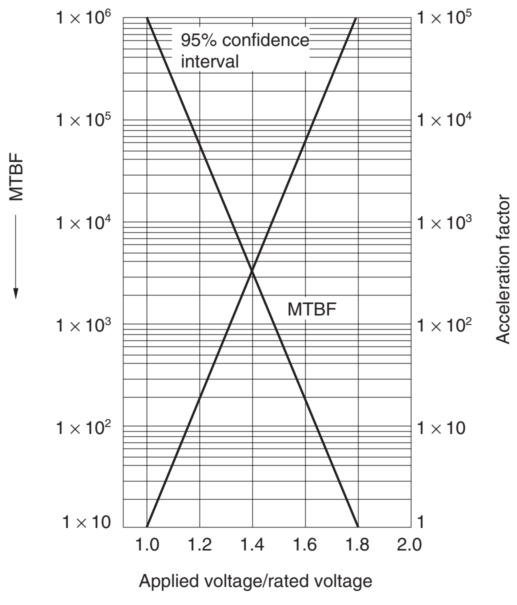


Figure 30. Relationship Between Voltage Stress and Acceleration Factor of Tantalum Capacitor

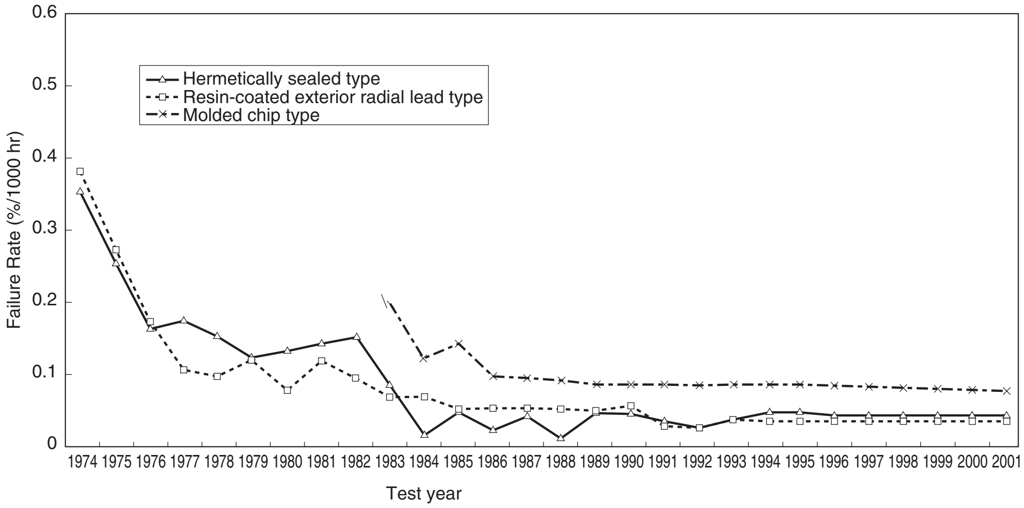


Figure 31. Failure Rate Data of Various Tantalum Capacitors

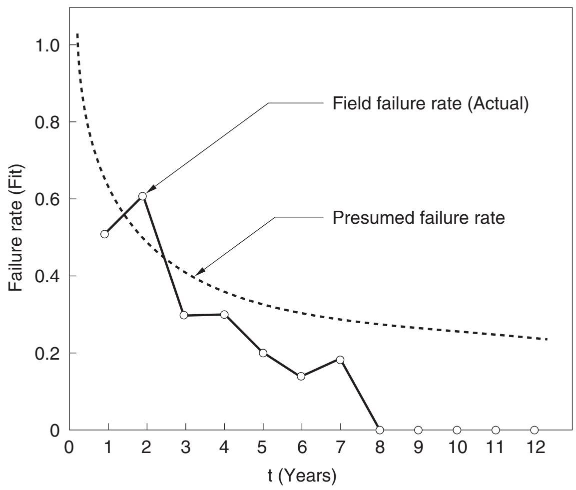


Figure 32. Field Data (Actual) and Presumed Failure Rate

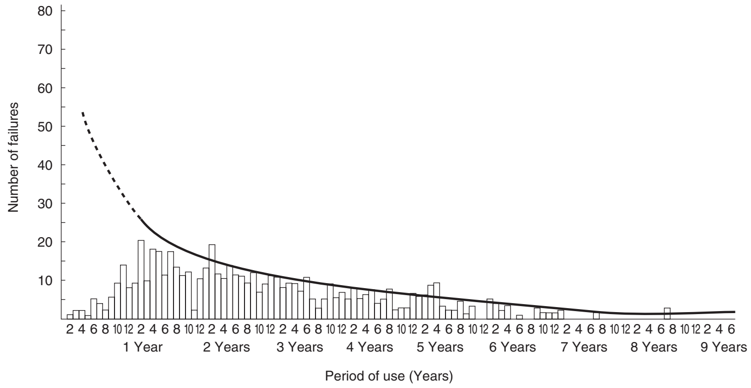


Figure 33. Pattern of Failure Occurrence of Tantalum Capacitors

8. Guidance

8.1 Reliability (Failure Rate) Estimation

Research into tantalum capacitor failure mainly has been advanced by the American military and is reported in standard materials such as MIL-HDBK-217 and MIL-STD-198D.

The majority of failures of tantalum capacitors in the field are leakage current increases or shorts. These are described below by inserting the contents of the above-mentioned use conditions.

When tantalum capacitor reliability is estimated, the following items are considered.

Failure rate of capacitor itself: λ_b

Factor from circuit design, capacitance value: π_{CV}

Factor from series resistance: π_{SR}

Factor as quality level: π_Q

Use environment factor: π_E

Case size or use environment correction: Σ_E

The actual failure rate λ_P is given by the following expression.

$$\lambda_P = \lambda_b \times (\pi_E \times \pi_{SR} \times \pi_Q \times \pi_{CV}) + \Sigma_E \qquad (16)$$

However, finding these correction factors is very difficult.

For λ_b, MIL-HDBK-217 inserts the voltage ratio and temperature factor for an electronic component and applies the following expression.

$$\lambda_b = A \left[\left(\frac{S}{N_S}\right)^H + 1 \right] e^{\left(\frac{T}{N_T}\right)^G} \qquad (17)$$

Where λ_b: Base failure rate expressed by a model relating the influence of electrical and temperature stress on the part

S: Ratio of operating voltage to rated voltage

T: Ambient temperature (K)

A: Capacitor type factor

NS: Stress factor

NT: Temperature factor

H, G: Acceleration factors

A tantalum capacitor is a component to which Arrhenius's equation (next page) is applied.

However, since it is very difficult to find individual correction factors, it is hard to estimate the actual failure rate using this expression. Accordingly, we take into account practical use and describe a procedure that allows us to estimate the failure rate more easily.

[Arrhenius's equation]

This is an equation for the velocity constant temperature change of a chemical reaction. The velocity constant is expressed by k = Aexp (–Ea/RT).

E: Activation energy, R: Gas constant, T: Absolute temperature

At a temperature (T_0) and a voltage (V_0) (generally the rated temperature and rated voltage), find the failure rate of the capacitor and make it the basic failure rate λ_0. It has been ascertained experimentally that the failure rate λ for the temperature (T) and operating voltage (V) in the field are approximated by the following expression(4). In other words,

$$\lambda = \lambda_0 \left(\frac{V}{V_0}\right)^n \bullet 2^{\left(\frac{T-T_0}{\theta}\right)} \qquad (18)$$

n and θ are parameters determined by the capacitor type. For tantalum capacitors, n = 3, θ = 10 have been found from experimental data.

Figure 34 illustrates expression (18). The vertical axis is the ratio of the actual failure rate to the failure rate λ_0 when tested at T0 = 85°C, V0 = rated voltage. The horizontal axis is the actual environmental temperature. The parameter of each graph is (Actual operating voltage)/(Rated voltage), which in general is called the derating ratio.

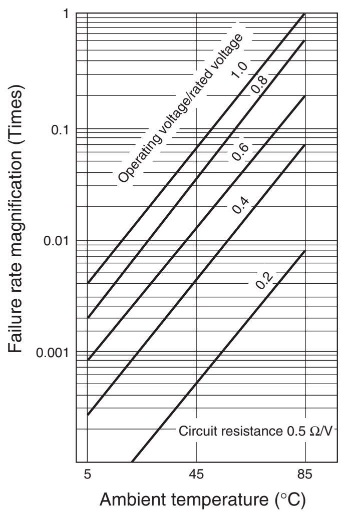


Figure 34. Relationship of Failure Rate to Operating Temperature and Applied Voltage

Figure 35 shows the data of MIL-HDBK-217. This indicates the relative failure rate in which the failure rate when tested at an ambient temperature of 85°C and the rated voltage is made 1.

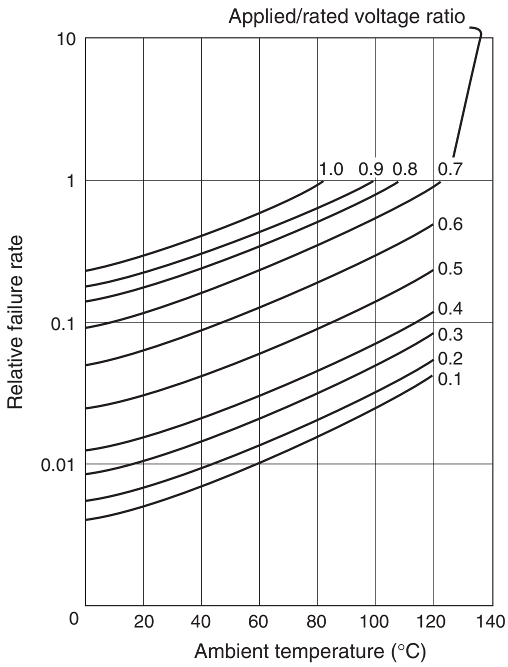


Figure 35. Relationship of Failure Rate to Operating Temperature and Applied Voltage in MIL Cases

As an example, Table 8 shows a case in which the field failure rate of a tantalum capacitor is used by a transmission device.

Table 8. Tantalum Capacitor Field Failure Rate

(Years 1981 to 2001)

Total number used	1,130,200
Component hours	128.23×10^9 h
Number defective	27
Failure rate	0.21Fit

Note Total number used is those used in the years 1981 to 2001

If we estimate the failure rate for an operating voltage/rated voltage ratio of 50% and an ambient temperature of 40°C using Figure 34, it is 0.005 times the failure rate for the rated voltage at 85°C, which approximates reality, but if we estimate it using the MIL-HDBK-217 graph (Figure 35), it is 0.03 times, which seems to be an order larger.

Expression (18) is extremely practical when estimating actual field failure rates.

Although expressions based on experimental results are a weak theoretical foundation, in the range of ratios (S) of operating voltage to rated voltage actually used in the field (for example the range 20 to 70%), they are in agreement with expression (18).

By expression (17), because of the fact that the failure rate for S = 0 (when the voltage load is 0)

$$\lambda_{b\,(S=0)} = Ae^{\left(\frac{T}{N_T}\right)^G} \qquad (19)$$

actually is extremely small, it is not considered in expression (18). In other words, although $\lambda = 0$ when $(V/V_0) = 0$ in expression (18), it is not actually 0 but a certain small value. However, compared to λ when a voltage load is applied, it is a value of an order that you may ignore.

8.2 Tantalum Capacitor Failure

(1) Failure mode

Over 95% of tantalum capacitor failures are due to leakage current increases and impedance increases. The latter is fatal if they occur in particularly high frequency signal transmission circuits. However, failures are mainly caused by the former. Moreover, if the leakage current in a circuit in which current flows increases in ampere (A) units, deterioration of the oxide film occurs due to generation of Joule heat, which may result in a short.

(2) Failure occurrence mechanism

There are various causes of failure, and there are causes that are inherent in the capacitor such as causes due to raw materials and the manufacturing process and external causes that are due to handling and use conditions. The relationships between various failure causes and processes (routes) resulting in failure are diagrammed in Figure 36.

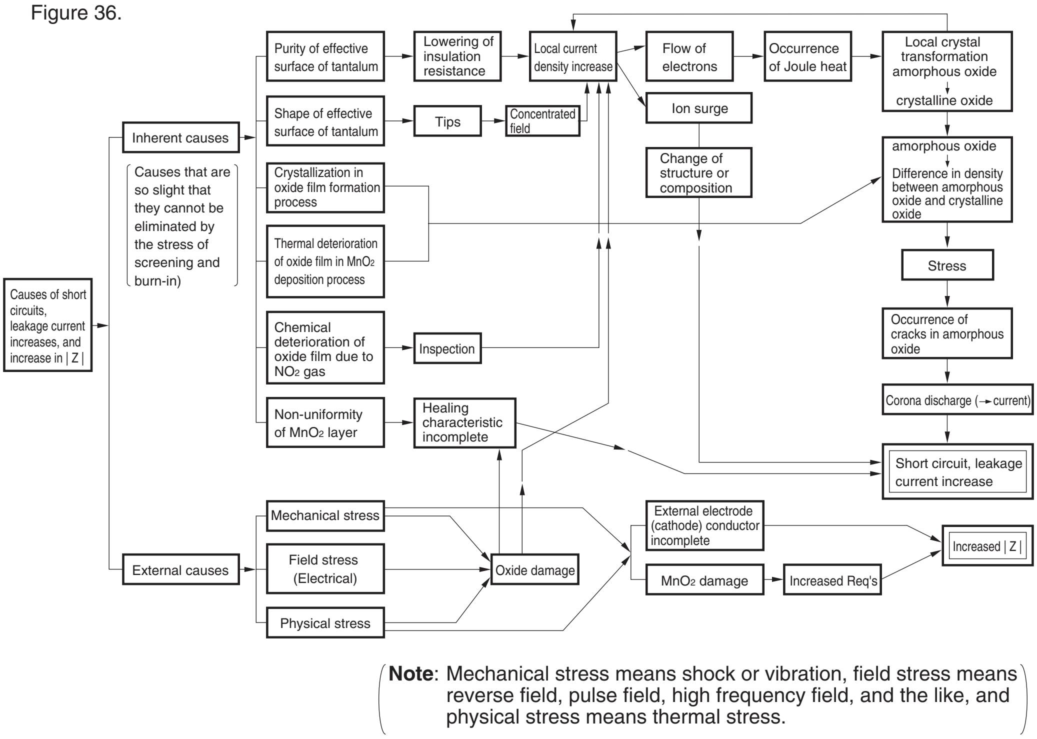


Figure 36. Causes of Tantalum Capacitor Failure (Short Circuit, Leakage Current Increase, Impedance) and Processes Leading to Each Failure (For MnO_2 Type)

As can be seen from the figure, causes related to leakage current failure occur far more frequently than causes related to impedance failure.

The reliability of tantalum capacitors is determined by the various inherent causes (defects) that are shown in Figure 25. If these defects could be made nil, reliability could be made infinitely high and failures made 0, but these defects cannot be made nil by current technology (such as raw material purification technology and capacitor manufacturing technology). At the current level of technology, reliability can be improved by lessening defects to realizable limits and then removing capacitors containing defects by screening. An important practical factor for reliability control is that capacitors are screened in order that only practically usable capacitors are distributed.

As the level of reliability that can be obtained at present, under operating conditions of ambient temperature 85?C at the rated voltage, 0.5%/10^3 hr is general for industrial communication equipment, and 1%/10^3 hr or less for personal use, but for satellite communication and undersea cable use, a high level of reliability of 0.1 to 0.01%/10^3 hr is demanded.

In general, for capacitors that contain some deterioration (inherent causes), the deterioration proceeds in accordance with various external stresses (e.g. temperature, voltage, mechanical vibration, and shock). Even if the degree of the deterioration is the same, the time until occurrence of failure (which can be thought of as a time equivalent to MTBF) will differ due to differences in use environments. For deterioration in defective areas of the dielectric film, that rate of progress varies in particular according to temperature and strength of electric fields applied to the film. On the other hand, for temperature, it follows Arrhenius's equation (P36).

The relationship between field strength and deterioration speed can be thought of as follows. As the defective part of the dielectric film deteriorates, the electric field of that portion increases. When deterioration reaches a level at which it cannot resist an externally applied field strength (in this case, this can be thought of as the capacitor's applied voltage), failure occurs. Accordingly, the lower the operating voltage is, the higher the reliability is obtained.

On the other hand, the relationship between ambient temperature and deterioration rate is such that when the temperature rises, the deterioration rate of the defective part is accelerated, and so MTBF becomes shorter. In other words, the reliability worsens.

These phenomena are explained in Figure 37 for ease of understanding.

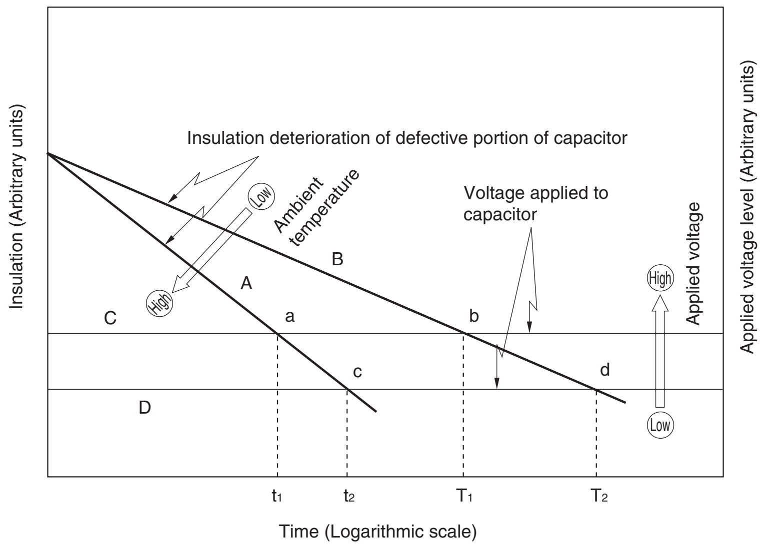


Figure 37. Relationship Between Capacitor Use Conditions and Time to Failure (Conceptual Diagram)

Lines A and B are graphs that represent the deterioration of the defective portion of the capacitor. Line A is a case in which the ambient temperature is higher than that represented by line B (the slope represents the deterioration speed and the steeper it is the greater the deterioration speed). Lines C and D are graphs that represent the voltage applied to the capacitor. At each graph intersection point a, b, c, d, capacitor failure occurs.

$T_1 > t_1$ and $T_2 > t_2$ clearly show that the higher the ambient temperature is, the lower the reliability of the capacitor is.

$T_2 > T_1$ and $t_2 > t_1$ clearly show that the smaller the voltage derating ratio is, the higher the reliability of the capacitor is.

However, the actual process leading to failure is not so simple, and there actually are many unclear points above, such as alternate effects of temperature and voltage, which are more complex and difficult to explain theoretically.

8.3 CV Value (Product of Capacitance and Applied Voltage) and Reliability

Figure 38 shows an example of the relationship between capacitor CV values and failure rates. As the CV value increases, the failure rate also increases. This is because various failure causes (inherent causes) shown in Figure 36 have an influence that increases proportionally with the capacitor effective surface area.

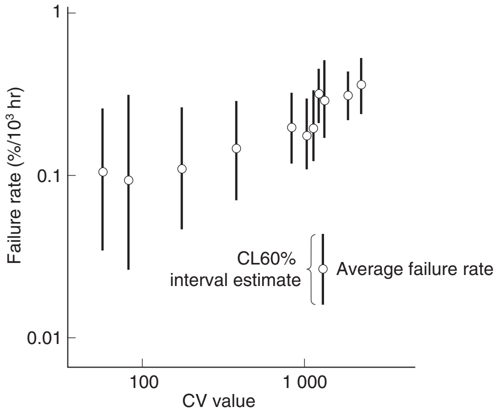


Figure 38. Relationship Between CV Value and Failure Rate (Example)

However, as you can see in Figure 38, failure rates and CV values are not totally proportional. The reason for this is that failure causes are the sum of factors that are totally proportional to the effective surface area of the capacitor and causes that have a constant degree of influence unrelated to CV values (effective surface area).

The former are factors such as tantalum purity, effective surface area shape, and dielectric film deterioration due to NOx gas. The latter are factors that result from the electrode drawer (electrode wire material purity, surface shape, electrode connector). In their correlations, graph slopes and causes are analogous to those in the previously described cases of CV value and leakage current.

8.4 Factors Influencing Reliability and Failure Rates

The reliability of a tantalum capacitor is also controlled by the appropriateness of handling by the user and the method of use (circuit design). As a consequence, reliability that is geared towards capacitor design will be reflected in the product based on how it is managed in each user department, so that it will be sufficiently maximized and utilized.

From this viewpoint, when actually using capacitors, shock, series resistance, ripple current, reverse voltage, and other factors that influence reliability must be sufficiently considered. (See the JEITA technology report (EIAJ-RCR-2368B.)

(1) Shock and reliability

In general, tantalum capacitors are like other electronic components in the way that their reliability is affected when shock is inflicted. Accordingly, be careful not to drop them on the floor before use or inflict other shocks. Moreover, do not use a capacitor on which shock has been inflicted, since its reliability may have been lowered.

Figure 39 shows an example of the relationship between the height of free fall and reliability (failure rate).

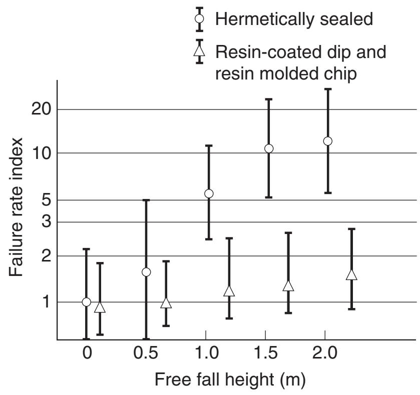


Figure 39. Relationship Between Free Fall Height and Failure Rate

The data in Figure 39 shows the failure rates of capacitors based on the following conditions:

(A) The capacitors are dropped on a concrete floor 10 times (free fall).

(B) They go through an endurance test.

The shock of falling was accelerated considerably and inflicted on the capacitor. Accordingly, for a capacitor with a high quality hermetically sealed structure, a deterioration trend is conspicuously shown. However, falling one time does not cause such an extreme decline in reliability.

Next, Figure 40 shows the relationship between shock strength and reliability using shock test equipment. Figure 41 shows the relationship between the capacitor's leakage current value and the number of falls when it is made to free-fall to a concrete floor from a 1-m height. Even after falling 15 times, leakage current deterioration is barely recognized.

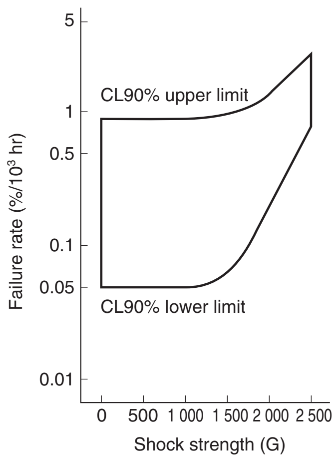


Figure 40. Relationship Between Shock Strength and Failure Rate (Hermetically Sealed Type)

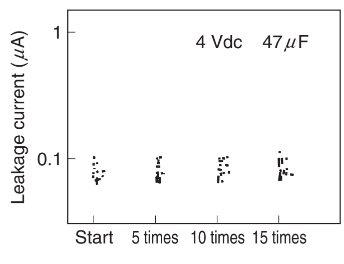


Figure 41. Relationship Between Number of Falls and Leakage Current (Chip Tantalum Capacitor)

In addition, Figure 42 shows the results of investigating the change in leakage current before and after shock testing. The test sample used had the same part numbers as that used in fall testing and the failure rate was found by executing an endurance test after inflicting shock in 6 directions 5 times each for a total of 30 times. The leakage current value is extremely stable and does not change even after receiving 2,000 G of shock, but reliability begins to decline in the 1,500 G vicinity.

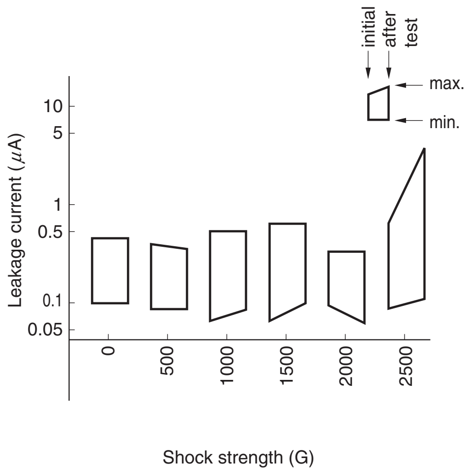


Figure 42. Change of Leakage Current Due to Shock Test (Hermetically Sealed Type)

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(2) Series resistance and reliability

Since resistance that is connected in series to the capacitor used (including circuit resistance) suppresses the capacitor's charge and discharge current, it lessens the field stress (for example, surge voltage or field shock) load on the capacitor's dielectric film. Accordingly, the series resistance (called R_S) has an influence on the reliability of the capacitor. The greater R_S becomes, the less the field stress on the dielectric film becomes. This leads to higher reliability.

Figure 43 shows the relationship between R_S and reliability (failure rate). The horizontal axis contains resistance values per volt of applied voltage and the vertical axis contains ratios in which 1 is the failures for 3Ω/V.

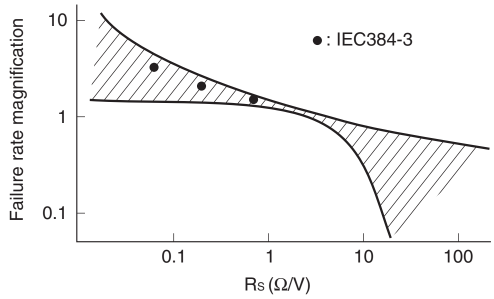


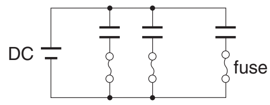
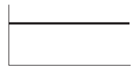
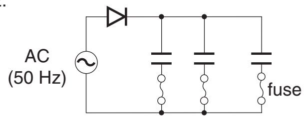
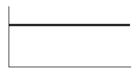
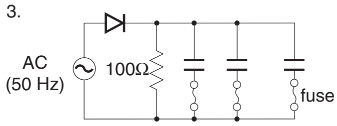
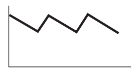
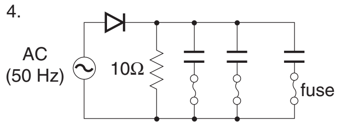
Figure 43. Relationship Between Series Resistance and Failure Rate

(3) Ripple and reliability

Because the internal resistance is comparatively large, tantalum capacitors are accompanied by heat generation due to ripple currents. When heat generation becomes excessive, deterioration of defective portions of the dielectric film accelerates, reliability declines, and MTBF is shortened. Care is needed in particular when using it for smoothing of a rectification circuit.

Table 9 shows an example of reliability test results used by circuits that contain a ripple component.

Table 9. Failure Rate When Voltage Containing Ripple Is Applied

Test Circuit	Voltage Waveform Applied to Capacitor	Failure Rate Magnification where Failure Rate Obtained by Test Circuit 1 is Made 1
1. 	 Ripple component 0%	1
2. 	 Ripple component 0%	1
3. 	 Ripple component 20%	8.09
4. 	 Ripple component 80%	56.7

Approximately 8 times the value is obtained where the applied voltage in the ripple component is 20%, and approximately 56 times the value where it is 80%. In other words, as the ripple content percentage increases, the failure rate also increases, so use below the derated voltage is recommended.

(4) Reverse voltage and reliability

Tantalum capacitors are polar, so avoid using them to continuously apply a reverse voltage.

It is not good for a polar tantalum capacitor to use it to continuously apply a reverse voltage. Since there are cases in which reverse voltage is applied to polar tantalum capacitors in circuit design, Figure 44 shows examples in which failure rates were found when various levels of reverse voltage were applied. The horizontal axis shows ratios of applied reverse voltage to rated voltage.

If there is a possibility that reverse voltage might be applied, consult NEC TOKIN beforehand.

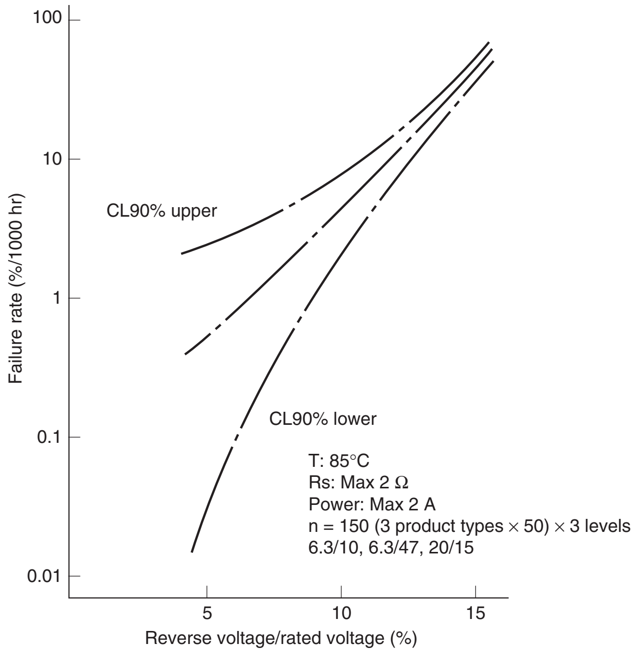


Figure 44. Failure Rates When DC Reverse Voltage Is Continuously Applied

Reference Documents

(1) R. L. Taylar and H. E. Haring; "A Metal-Semiconductor Capacitor"
: J. ElectrocheSoc., Vol. 109 Nov. 1956 pp. 611

(2) Ishikawa, Sasaki: "Tantalum Electrolytic Condenser Mechanisms using PIN Junction Model": Physical Society of Japan Lecture Notes 364, 1955

(3) RADC Note Book, Vol2 (1974)

(4) Okuda and others: NEC Technical Journal, No. 91 (1968)

(5) MIL-HDBK-217A (1965, 12)

(6) Y. HASEGAWA and K. MORIMOTO: "Characteristics and Failure Analysis of Solid Tantalum Capacitors"
: NEC R&D., No. 50 pp. 79-94 July 1978

8.5 Shorting

Tantalum capacitors, like ceramic capacitors and other components, may short and burn in circuits in which a large current flows. In addition, the burn state differs according to whether the cathode material is MnO2 or a conductive polymer (NeoCapacitor). To help you to understand these points, we provide an introduction to the processes that lead to shorts and burning.

(1) Tantalum capacitor (MnO_2 type)

Figures 45 and 46 simply show the tantalum capacitor burn mechanism and presumed pattern.

When a capacitor fails and shorts, joule heat occurs due to the short current flowing at the deterioration site. Deterioration is accelerated by the joule heat and the short current increases. If the short current increase continues, the generated heat also reaches high temperatures, which leads to burning of the capacitor.

An intrinsic factor of tantalum capacitors (MnO_2 type) is that in a burning state, since oxygen is supplied by the MnO_2 that is used as the electrode material, an oxidation reaction is promoted accompanying the tantalum metal heat generation, which leads to intense heat (Table 10). Even though a flame-retardant resin (UL94V-0) is used as molded resin, it may ignite in intense heat if the worst should occur. (Figure 46 <1>)

Therefore, for a power supply circuit or other low impedance circuit, it is recommended that you maintain equipment reliability by using a current limitation circuit (less than 1 A is desirable) or use 30% to 50% of the rated voltage.

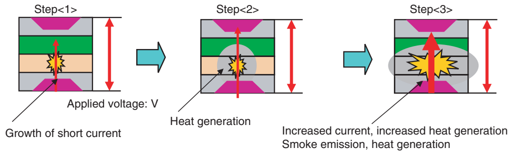


Figure 45. Mechanism Leading to Short Failure

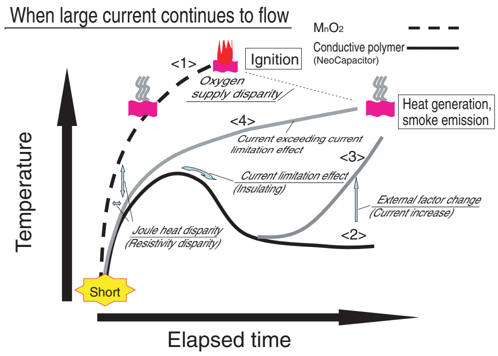


Figure 46. Presumed Pattern of Burning

Table 10. 3 Elements of Burning and Smoking

No	Burning and Smoking Elements	Tantalum Capacitor (MnO2)
1.	There must be burning material or combustible material	Tantalum metal Oxidation reaction accompanying heat generation [See Supplemental notes]
2.	It must be heated to the temperature at which the combustible material ignites or higher, and there must be an ignition source	Heat generation due to short (Local temperature rise)
3.	There must be a supply of oxygen	MnO_2 is an oxygen supply source

(2) Conductive polymer tantalum capacitor (NeoCapacitor)

When a conductive polymer is used in the electrode material, the burning state on a short is lessened. Table 11 shows a comparison of the main physical attributes of MnO_2 and the conductive polymer material.

Table 11. Comparison of Electrode Materials

Electrode Material	Oxygen Supply Volume (Ratio)	Resistivity (Ratio)	Pyrolyzing Temperature
Manganese dioxide (MnO_2)	1	1	500°C or higher
Conductive polymer	0.001	0.01	About 300°C

Firstly, the oxygen supply volume of the conductive polymer material is 1/1000 that of MnO_2 and it has a tendency to suppress the tantalum metal oxidation reaction.

Secondly, the resistivity of the conductive polymer material is a small value that is 1/100 that of MnO_2. Accordingly, immediately after a short the amount of heat generation on the cathode layer side is small.

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Thirdly, the conductive polymer material has characteristics as a so-called pyrolyzing polymer at comparatively low temperatures (about 300°C). Therefore, the entire cathode layer has insulation characteristics due to heat generation, which has the effect of restricting (changing to open) the short current (Figure 47).

The pattern of burning surmised from these facts is shown as <2> <3> and <4> in Figure 46.

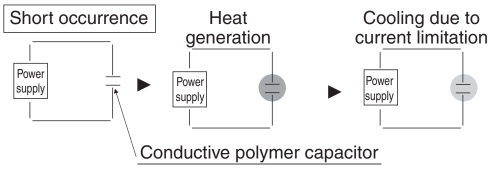

Figure 47. Current Limitation Effect in Case of Shorting

For a conductive polymer type, the resistivity is small, so the amount of heat generation of the cathode layer immediately after a short is checked and the temperature rises gently compared to the MnO_2 type (<1>). When a certain temperature is reached, current limitation results from conductive polymer insulating and a thermal equilibrium state comes about after the temperature decreases (<2>). However, if the applied voltage, external temperature, or other external factors change and the current increases, it may rise again and there may be heat generation and smoke emission (<3>). Depending on the size of the current, the current suppression effect due to insulating also might be exceeded and in this case the temperature could continue to rise and generate heat and smoke (<4>). In this heat generation and smoke emission state, the tantalum metal oxidation reaction is suppressed because the oxygen supply volume from the cathode layer is small, the temperature from heat generation is low, and the degree of burning is less than for the MnO_2 type.

(3) Referenced experiments

Figure 48 shows the results of an experiment that measured chip surface temperatures while an AC voltage of 10 kHz was applied. The MnO_2 type shorted at a Vp-p of 3.0 V or more, which led to smoke emission and ignition, but the conductive polymer type (NeoCapacitor) did not short, and once the peak temperature was reached it started falling. In addition, the temperature of the surface of the conductive polymer type (NeoCapacitor) did not rise remarkably.

Figure 49 shows experimental results compared after simulating burning states.

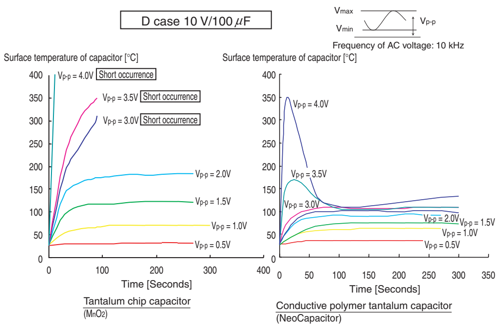

Figure 48. AC Voltage Application Experiment

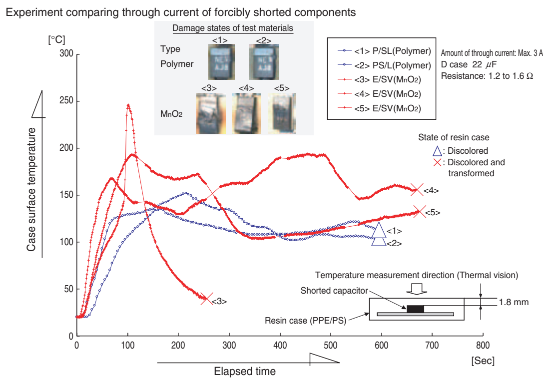

Figure 49. Burning Accident Simulation Experiment

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This is an experiment that was conducted as follows: (1) reverse voltage was applied to the samples (D case size, 22 μF) of the E/SV series (MnO_2) and the PS/L series (conductive polymer); (2) the samples were momentarily shorted; (3) a DC power supply adaptor (Max. 3A) was connected to them; and (4) current continuously conducted into them. Each sample was covered by a resin case serving as a simulated device case, with a 1.8-mm clearance being provided between the case and the top of the sample.

Then, changes in temperature on the top surface of each case were measured with thermal vision. After the energization was over, the appearance of each sample and that of each case were observed and compared.

Although the variation in case surface temperature change was great for each test sample, results showed that the case surface temperature rise for the conductive polymer type test sample was gentle and the peak temperature low compared to the MnO_2 type test sample. In addition, the appearance of the MnO_2 type test sample after the through current leads to a speculation that ignition might have occurred in the test sample, while in contrast, the degree of burning of the conductive polymer type test sample was slight. As to the burned state of the resin case, although transformation was recognized for the MnO_2 type of test sample and it was indicated that intense heat had occurred, for the conductive polymer material it stopped at discoloration.

(4) Conclusions

When tantalum capacitors are shorted, they may burn due to the flowing current.

When conventional tantalum capacitors (MnO_2) burn, an oxidation reaction is promoted along with tantalum metal heat generation due to an oxygen supply from the MnO_2. The oxidation reaction easily leads to intense heat, and even flame retardant molded resin (UL94V-0) may result in ignition. Therefore, for a low impedance circuit in which large currents flow, the most redundant design possible must be considered.

In the conductive polymer type of capacitor (NeoCapacitor), the progress of a burning state is suppressed due to the small oxygen supply volume, low resistivity, and low pyrolysis temperature of the conductive polymer material compared with the conventional type of tantalum capacitor (MnO_2). The point that should be noticed in particular is that in comparisons under the same conditions the time leading to burning after shorting lengthens. Accordingly, it is possible to more easily prevent burning accidents on shorting by using appropriate guard circuits or the like.

However, burning phenomena after capacitor failure are caused by various factors. Chance and various other factors lead to shorting of capacitors; furthermore external factors have a complex effect on the states of the capacitors. Therefore, it is difficult to perfectly reproduce the shorting conditions and to explain theoretically which factor has led to the short failure. There are many unclear factors. Although the contents described above are qualitatively correct, they do not explain everything.

Still, even for conductive polymer capacitors, the best countermeasure is not to cause shorts. It is necessary to assure reliability by referring to the use precautions in circuit design.

[Supplemental notes]

* Reference materials · · · EIAJ RCR 2368B "Precautions for Tantalum Solid Electrolytic Capacitors Use"
* Tantalum metal combustibility

Tantalum metal oxidation is a reaction that generates heat according to a thermochemical equation.

$2Ta + \frac{5}{2} O_2 = Ta_2O_5 + 2044$ KJ/mol · · From the "Metal Data Book"

When the metal oxidation is calculated by the above expression and the amount of tantalum used in the D case, it is 1.95 kJ, which corresponds to 466 cal.

If converted for the specific heat of tantalum metal, this corresponds temperature-wise to 3000°C. However, this is not actually possible if total heat radiation is not assumed.

* Atomic weight of tantalum: 180.9, 1 cal: 4.186 J

9. Sample Application Circuit

A tantalum capacitor has the following features compared to an aluminum electrolytic capacitor.

(1) Small size

(2) Low leakage current

(3) Favorable frequency characteristics

(4) Favorable characteristic changes due to temperature

(5) Small equivalent series resistance

(6) Long life

The main uses for taking advantage of the features of tantalum capacitors are (1) For bypass, (2) For coupling, (3) For decoupling for power supply, and (4) For backup, as explained in "5. Uses and Roles of Capacitors" of OVERVIEW OF CAPACITORS.

A typical application example for each is introduced below.

9.1 For Bypass

■ PHS

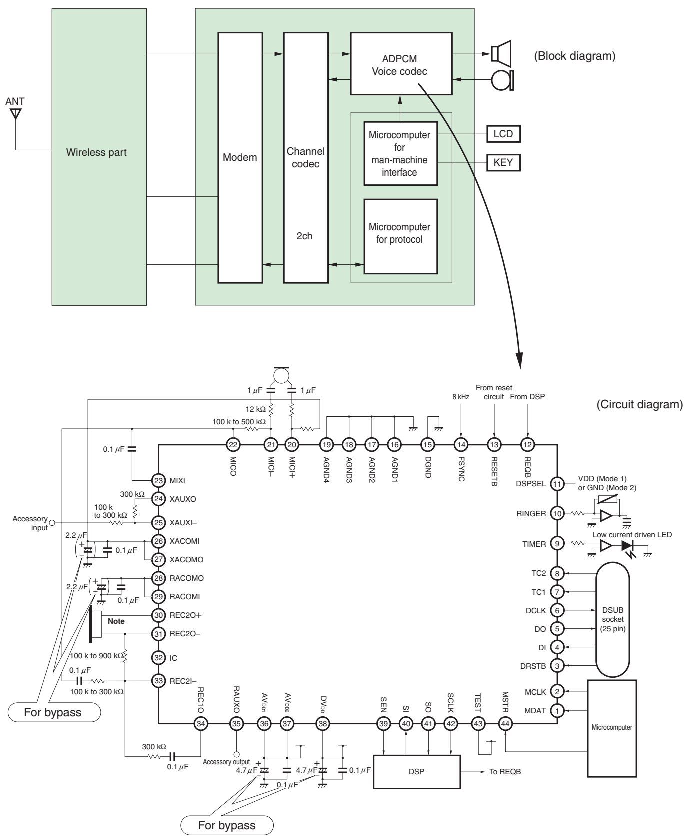

Figure 50. Application Example for Bypass

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9.2 For Coupling

■ Digital still camera

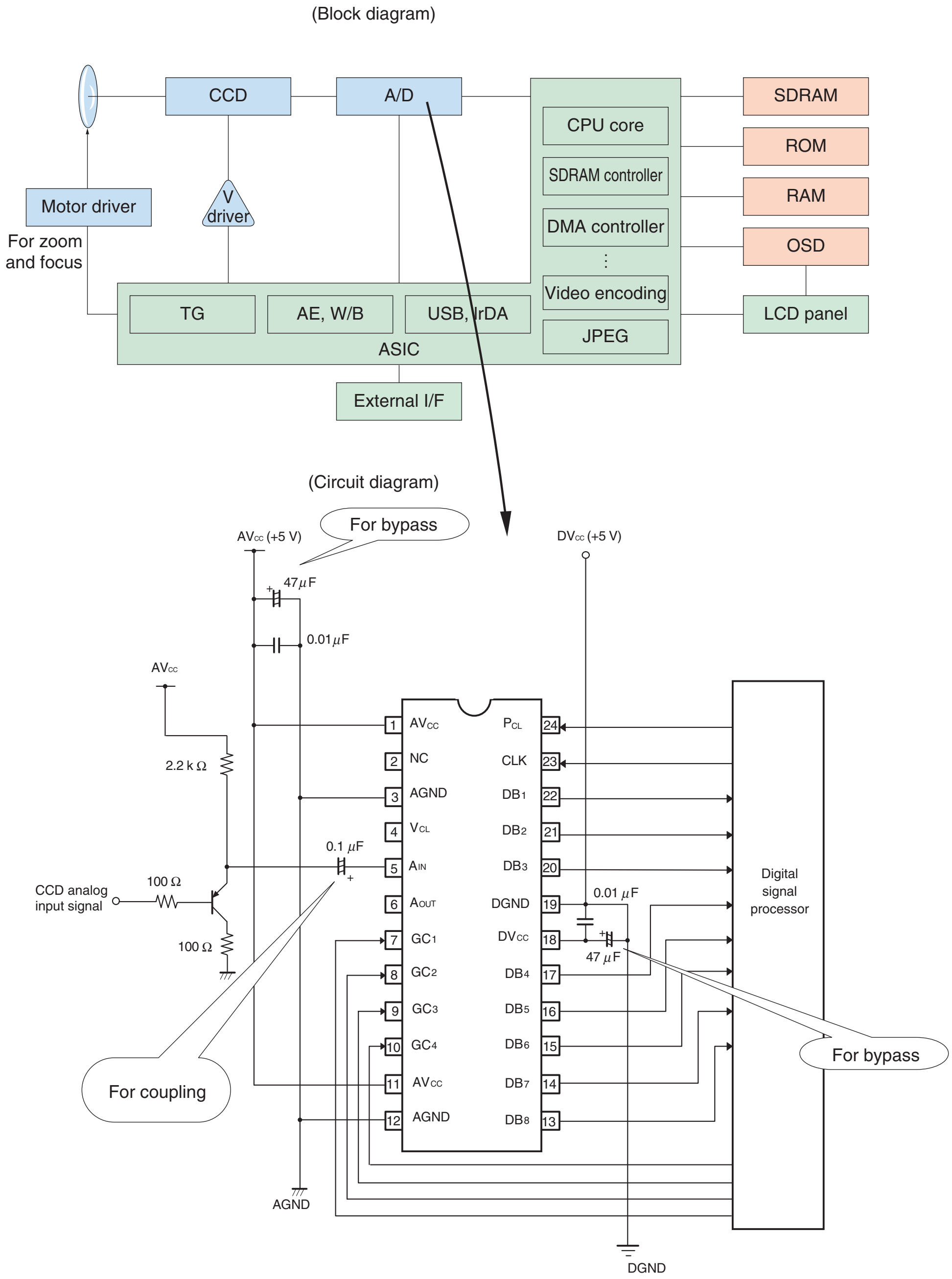

Figure 51. Application Example for Coupling

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9.3 For Smoothing of Power Supply Output

■ Power supply

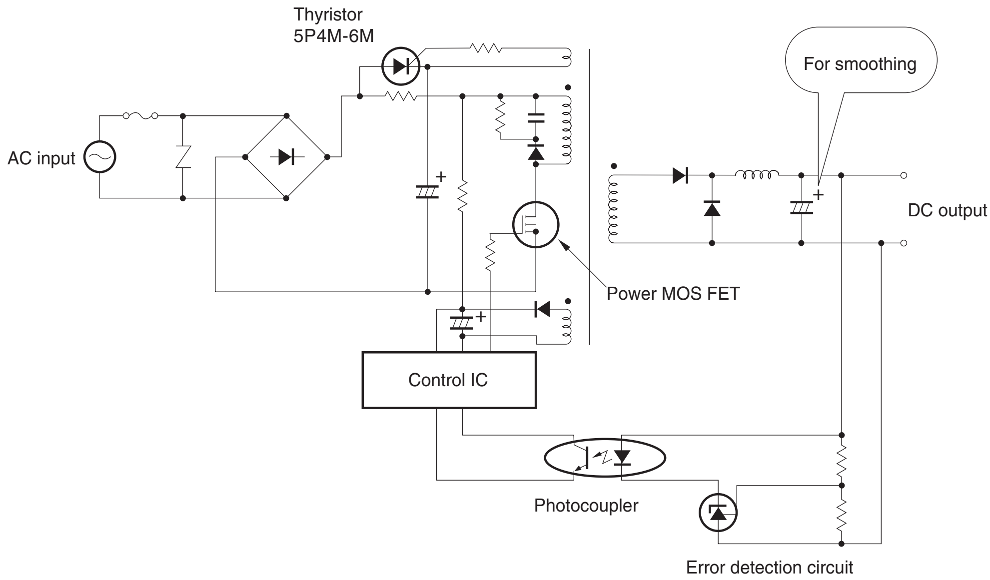

Figure 52. Application Example for Smoothing

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9.4 For Current Fluctuation Buffering

■ Motherboard

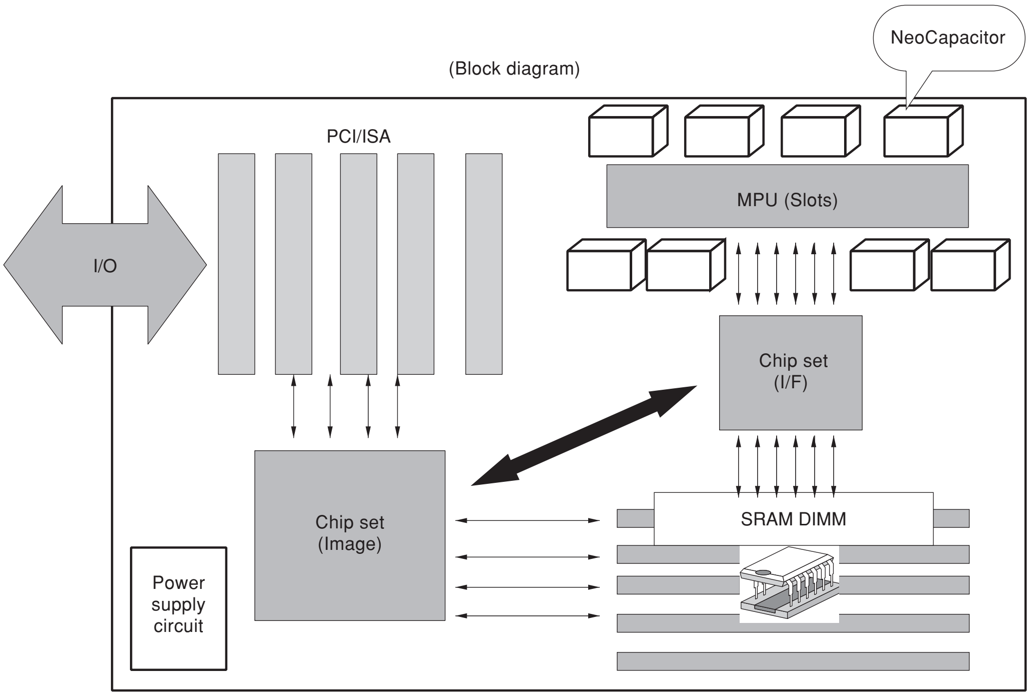

Figure 53. Application Example for Current Fluctuation Suppression

ICs and LSIs (e.g. high-performance MPUs) that consume large amounts of current and that operate at high speed have a function for abruptly changing their operation mode to reduce power consumption. Accordingly, current in the power supply line greatly fluctuates depending on changes in the operation mode. To suppress the fluctuation, the NeoCapacitor, a capacitor featuring low ESR and large capacity is required.

10. Test Methods and Criteria

A summary of some of the JIS standards and IEC standards for tantalum capacitors is given below for reference.

Table 12. JIS Standards for Tantalum Capacitors (JIS C 5101-1) and Conforming IEC Standards (IEC 60384-1)

	Item	Test Method (JIS C 5101-1 1998) or Interpretation	Criteria and Supplemental Explanation
1	Operating temperature range (°C)	Expresses the range of ambient temperatures in which the capacitor can be continuously used.	Expresses the interval between the maximum operating temperature and minimum operating temperature, which includes the rated temperature (maximum operating temperature at rated voltage). Specified for each product series.
2	Rated temperature at rated voltage (°C)	Expresses the maximum value of ambient temperatures at which the rated voltage can be applied to the capacitor and at which the capacitor can be continuously used.	Specified for each product series.
3	Rated voltage	Expresses the maximum value of peak voltage (sum of DC voltage and permissible AC peak voltage) that can be applied continuously to the capacitor at the rated temperature (maximum operating temperature at the rated voltage).	
4	Leakage current	Series protective resistance: Approx. 1 kΩ Applied voltage: Rated voltage Measurement time: For 5 minutes after the rated voltage is achieved. However, if the current value is less than the criterion value and is decreasing further or is stable, measurement time can be less than 5 minutes.	Expresses the current value when the criterion time has elapsed after applying the criterion DC voltage between terminals. Specified for each product model.
5	Capacitance	Measurement frequency: 120 Hz ±20% Measurement circuit: Equivalent series circuit  Measurement voltage: 0.5 Vrms or less, +1.5 to 2.0 VDC However, if there is no doubt about the decision, it may not be necessary to superimpose the DC voltage.	A nominal value of capacitance and permissible range are specified for each product model.
6	Dissipation factor	Same as above	A maximum value is specified for each product model.
7	Impedance	Measurement frequency: 100 kHz ±10% Make sure that the value of the measurement voltage or the current flowing in the test capacitor does not change even after the voltage is applied continuously for 1 minute. However, the measurement voltage must not exceed 0.5 Vrms.	A maximum value is specified for each product model.
8	Resistance to soldering heat	Based on JIS C 0050 (IEC68-2-20) test method (Solder dip at 260°C). Solder: H60A or H63A Flux: Ethanol solution of rosin (25 Wt%) Solder temperature: 260 ±55°C Solder immersion time: 5 ±1 seconds (10 ±1 seconds depending on product series) Immersion depth: Depth of 10 mm from soldering bath surface (Immerse entire capacitor by holding by pin set) Flux cleaning: Immerse in isopropyl alcohol for 5 ±1 minutes	Appearance: Not abnormal. Marking must be easily readable. Rate of change of capacitance: Within criterion rate of change Dissipation factor: According to the initial specifications Leakage current: According to the initial specifications

	Item	Test Method (JIS C 5101-1 1998) or Interpretation	Criteria and Supplemental Explanation
9	Solderability	Conforms to JIS C 0054 (IEC68-2-58) Solder: H60A or H63A Flux: Ethanol solution of rosin (25 Wt%) Solder temperature: 215°C ±3°C Solder immersion time: 3 ±0.3 seconds Immersion depth: Depth of 10 mm from soldering bath surface (Immerse entire capacitor by holding by pin set)	95% or more of the terminal surface must be covered by new solder.
10	Robustness of termination	Conforms to JIS C 0051 (IEC68-2-21).	Appearance: Must be no detachment of terminals.
11	Bond strength of face plating	Conforms to JIS C 5101-1 test method (Bond strength of electrodes) in accordance with JIS C 0051 (IEC68-2-21)	Appearance: Not abnormal. Marking must be easily readable. Capacitance: Values measured during test must be stabilized.
12	Temperature cycle	Number of temperature cycles: 5 cycles Cycle: 1 cycle is composed of stages 1 to 4 in the table below. (see stage table below) Recovery: Leave the capacitor in the standard atmospheric conditions for 1 to 2 hours.*	Appearance: Not abnormal. Marking must be easily readable. Rate of capacitance change: Within criterion rate of change Dissipation factor: According to initial specifications Leakage current: According to initial specifications
13	Climatic sequence	Conforms to JIS C 5101-1 test method (Climatic sequence) in accordance with JIS C 0020 (IEC68-2-1), JIS C 0021 (IEC68-2-2), JIS C 0027 (IEC68-2-30), and JIS C 0029 (IEC68-2-13). Perform tests in order of the following items. (see order table below)	Appearance: Not abnormal. Marking must be easily readable. Rate of capacitance change: Within criterion rate of change Dissipation factor: According to the individual specifications Leakage current: According to the individual specifications
14	Damp heat (Steady state)	Conforms to JIS C 5101-1 test method in accordance with JIS C 0022 (IEC68-2-3). Test temperature: 40 ±2°C Relative humidity: 90 to 95% Test time: Time prescribed by product ratings	Appearance: Not abnormal. Marking must be easily readable. Rate of capacitance change: Within criterion rate of change Dissipation factor: According to the individual specifications Leakage current: According to the individual specifications

Item 12 stage table:

Stage	Test Temperature	Time (min.)
1	Minimum operating temperature ±3°C	30 ± 3
2	Normal temperature	No more than 3
3	Minimum operating temperature ±2°C	30 ± 3
4	Normal temperature	No more than 3

Item 13 order table:

Order	Item	Test Conditions
1	High temperature	Maximum operating temperature ±2°C 16 ±1 hours
2	Damp heat, cyclic	First cycle of Method 2 1 cycle: 24 hours Temperature: 55 ±2°C
3	Low temperature	Minimum operating temperature ±3°C 2 to 3 hours
4	Low air pressure	Pressure: 8.5 kPa 10 minutes
5	Damp heat, cyclic	Remaining cycle of Method 2 1 cycle: 24 hours Temperature: 55 ±2°C
6	Final measurement	Standard atmospheric conditions*

<table>
<tr><th colspan="2">Item</th><th>Test Method (JIS C 5101-1 1998) or Interpretation</th><th>Criteria and Supplemental Explanation</th></tr>
<tr><td>15</td><td>Characteristics at high and low temperature</td><td>Conforms to JIS C 5101-1 test method (Characteristics at high and low temperature). Maintain temperatures at the stages in the following table and measure the electrical characteristics once thermal equilibrium is reached at the temperature of each stage.
<table>
<tr><th>Stage</th><th>Temperature</th></tr>
<tr><td>1</td><td>20 ± 2°C</td></tr>
<tr><td>2</td><td>Minimum operating temperature ±3°C</td></tr>
<tr><td>3</td><td>20 ± 2°C</td></tr>
<tr><td>4</td><td>Maximum operating temperature ±3°C</td></tr>
</table></td><td>Appearance: Not abnormal.
Marking must be easily readable.
Rate of capacitance change:
Within criterion rate of change
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
<tr><td>16</td><td>Surge</td><td>Conforms to JIS C 5101-1 test method (Surge)
Test temperature: 85 ±2°C
Protective resistance: 1000 Ω ±10%
Charge time (30 ±5 sec.) discharge time (6 ±0.5 sec.) charge-discharge cycle for 1000 cycles</td><td>Appearance: Not abnormal.
Marking must be easily readable.
Rate of capacitance change:
Within criterion rate of change
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
<tr><td>17</td><td>Endurance</td><td>Conforms to JIS C 5101-1 test method (Endurance).
Test conditions and test times
<table>
<tr><th colspan="2">Test Conditions</th><th rowspan="2">Test Time</th></tr>
<tr><th>Test Temperature</th><th>Applied Voltage</th></tr>
<tr><td>85 ± 2°C</td><td>Rated voltage</td><td rowspan="2">2000 to 2072 hours</td></tr>
<tr><td>125 ± 2°C</td><td>Derated voltage</td></tr>
</table>
Power supply impedance: No more than 3 Ω
Recovery: Leave the capacitor in the standard atmospheric conditions for 1 to 2 hours.*</td><td>Appearance: Not abnormal.
Marking must be easily readable.
Rate of capacitance change:
Within criterion rate of change
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
<tr><td>18</td><td>High surge current (This test is applied when required by the individual specification for the electrolytic capacitor with solid electrolyte.)</td><td>Conforms to JIS C 5101-1 test method (High current surge).
(Conforms to IEC60384-1)
Test temperature: 23±3°C
Test voltage: Rated voltage ±2%
Charge and discharge: Repeat 1 second charge and 1 second discharge 4 times
Fuse: Use either a wire fuse that melts at 0.5 to 2 A or an electronic circuit that operates in the same current range.
Discharge resistance: 0.05 to 0.2</td><td>Appearance: Not abnormal.
Marking must be easily readable.
Capacitance: Within the specified permissible tolerance of criterion
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
<tr><td>19</td><td>Resistance to vibration</td><td>Conforms to JIS C 5101-1 test method (Vibration).
For the capacitor, perform the test based on the criteria in JIS C 0040:1999 (IEC60068-2-6:1995) and according to the methods and strictness in related standards.</td><td>Appearance: Not abnormal.
Marking must be easily readable.
Capacitance: Within the specified permissible tolerance of criterion
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
<tr><td>20</td><td>Shock (or bump)</td><td>Conforms to JIS C 5101-1 test method (Shock or bump).
For the capacitor, perform the test based on the criteria in JIS C 0041 (IEC68-2-27) or JIS C 0042 (IEC68-2-29) and according to the methods and strictness in related standards.</td><td>Appearance: Not abnormal.
Marking must be easily readable.
Capacitance: Within the specified permissible tolerance of criterion
Dissipation factor: According to the individual specifications
Leakage current: According to the individual specifications</td></tr>
</table>

* "Standard atmospheric conditions" are those prescribed in JIS C 0010. Temperature: 15 to 35°C
Relative humidity: 25% to 75%
Air pressure: 86 kPa to 106 kPa

PRECAUTIONS FOR TANTALUM CAPACITOR USE

Most of the complaints about tantalum capacitors in the field concern leakage current increases or short defects. In circuit design, observe the precautions below and make the design as redundant as possible.

1. Circuit Design

(1) Estimation of field failure rate

Up to 90% of the failure rate of this capacitor in the field is leakage current increases and shorts.

When estimating the field failure rate, the voltages and temperatures that give rise to these leakage current increases or shorts are parameters.

When only temperature and voltage are the parameters of an expression for estimating a tantalum capacitor's failure rate in the field, the expression is as follows.

$$\lambda = \lambda_0 \left(\frac{V}{V_0}\right)^3 \bullet 2^{\frac{(T-T_0)}{10}}$$

λ: Presumed failure rate in operating state
T: Operating temperature
V: Operating voltage
λ_0: Failure rate under rated load (Table below)
T_0: Temperature for rated load (85°C)
V_0: Voltage for rated load (Rated voltage)

Table 13. Failure Rate Level λ_0 of Each Series

Series	λ_0
E/SV	1%/1000 h
SV/Z	1%/1000 h
F/SV	1%/1000 h
PS/L	1%/1000 h
PS/G	1%/1000 h

<Test Conditions>
Temperature: 85°C
Voltage: Rated voltage
Series resistance: 3 Ω

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(2) Permissible ripple current and voltage

When you apply a ripple current and voltage to a capacitor, its temperature rises due to Joule heat (power dissipation), and this influences its reliability.

<1> The power dissipation P is defined by expression 1.

$P = I^2 \times ESR$ ··· Expression 1

P: Power dissipation (Watts)
I: Ripple current (Arms)
ESR: Equivalent series resistance (Ω)

Table 14 shows the permissible power dissipation value P (f = 100 kHz, at 25°C) for each case size.

Table 14. Permissible Power Dissipation

Case Size	Permissible Power Dissipation Value P (Watts) f = 100 kHz, at 25°C
J	0.010
P	0.025
A2	0.060
A	0.075
B3	0.075
B2	0.085
C2	0.090
C	0.110
V	0.125
D	0.150

<2> The permissible ripple current I (Arms) is computed by expression 2.

$I = \sqrt{P/ESR} \times K \times F$ ··· Expression 2

(K: Temperature derating factor ··· Table 15
F: Frequency correction factor ··· Table 16)

✧ Compute the permissible ripple current of the E/SV, F/SV, and SV/Z series from the ESR standard values in the product list and expression 2.

✧ For the PS/L and PS/G series, see the individual catalog and 5 (1).

Table 15-1. E/SV, F/SV, SV/Z Series

Operating Temperature	Temperature Derating Factor K
25°C	1
85°C	0.9
125°C	0.4

Table 15-2. PS/L, PS/G Series

Operating Temperature	Temperature Derating Factor K
25°C	1
85°C	0.9
125°C	0.4

<3> The ripple voltage E is computed from the impedance Z by expression 3.

$E = Z \times I$ ··· Expression 3

Table 16. Frequency Correction Factor F

Series	10 kHz	100 kHz	500 kHz	1 MHz
I	0.80	1.00	1.15	1.20
II	0.75	1.00	1.10	1.30

I: FE/SV, F/SV, SV/Z
II: FPS/L, PS/G

Note the points below concerning ripple voltage.

(a) Make sure that the sum of the peak values of DC voltage and ripple voltage do not exceed the rated voltage.

(b) Make sure that reverse voltage does not occur due to variations in weighted voltage.

(c) Make sure that the permissible ripple current is not exceeded.

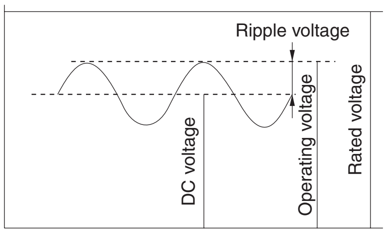

Figure 56. Ripple Voltage Waveform Diagram

* Since ESR and impedance differ according to capacitance and operating frequency, consult NEC TOKIN for details.

(3) Reverse voltage

Because a tantalum capacitor is polar, a decline in reliability due to reverse voltage application is recognized. Do not apply reverse voltage. Figure 54 is the result of testing at NEC TOKIN, but if reverse voltage/rated voltage exceeds 5% at a high temperature, reliability declines sharply.

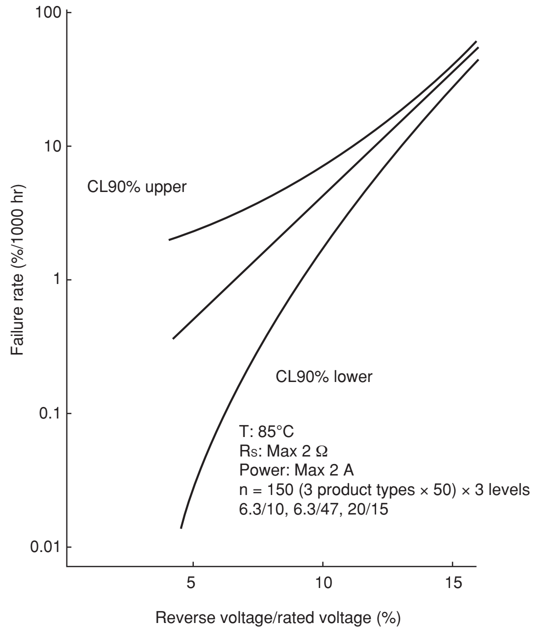

Figure 54. Failure Rate When DC Reverse Voltage Is Continuously Applied

Figure 55 shows the relationship between leakage current and reverse voltage (it does not show the bounds of reverse voltage application).

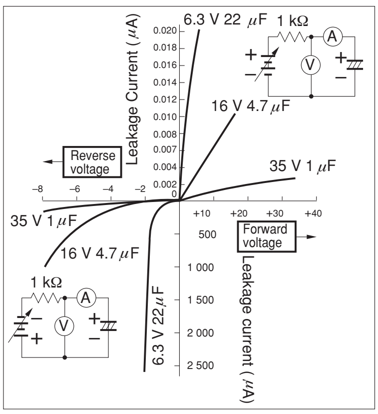

Figure 55. Tantalum Capacitor Current - Voltage Characteristics

(4) Applied voltage

As shown in the field failure rate estimating expression on page 54, applied voltage has a great influence on reliability. Accordingly, if high reliability is desired, use at a low voltage is recommended. In general, 60 to 70% of the rated voltage is used for the voltage that is applied.

In addition, the leakage current increases exponentially to the applied voltage, as shown in Figure 57. If leakage current is a problem, use at a low voltage is recommended.

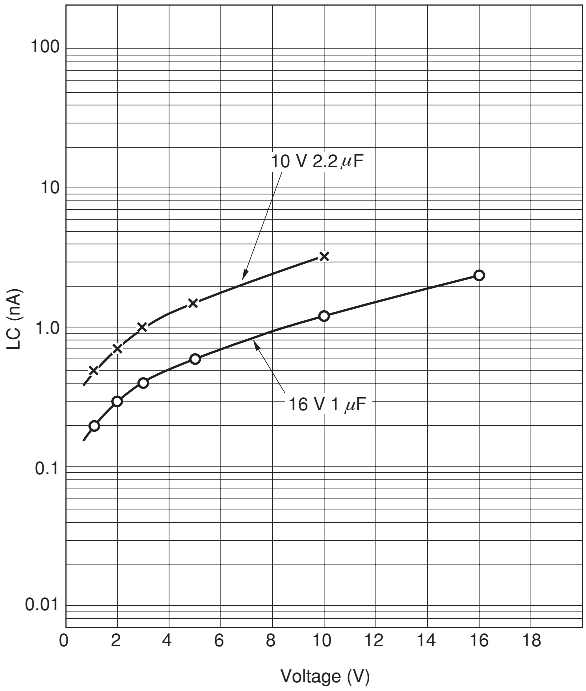

Figure 57. Relationship Between Leakage Current and Applied Voltage

When a tantalum capacitor is connected to a power supply line, the power supply impedance seen from the capacitor is small, so the failure rate increases as shown in Figure 58. Accordingly, it is recommended that there be sufficient voltage derating (1/2 to 1/3). Table 18 shows examples of recommended ratings corresponding to the voltage that you use.

Table 18. Examples of Recommended Operating Voltages

Operating Voltage	Rated Voltage
5 Vdc	16 V
12 to 16 Vdc	35 V

(5) Current

Figure 58 shows the experimentally confirmed relationship between series protective resistance and the failure rate of tantalum capacitors.

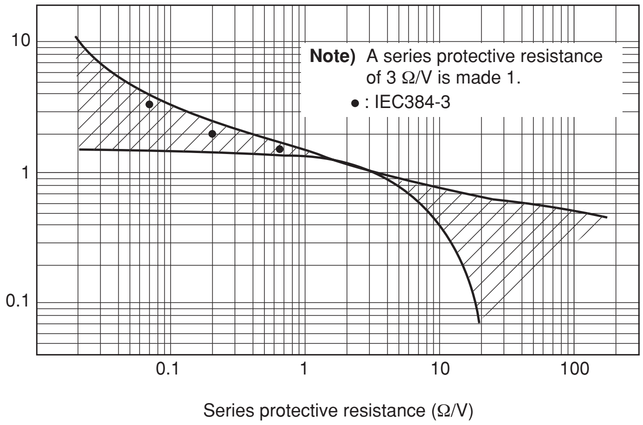

Figure 58. Relationship Between Series Resistance and Failure Rate

As seen from this figure, it is possible to obtain higher reliability by current limitation done by raising the series protective resistance (power supply impedance seen from capacitor side). In particular, current limitation must be considered for a circuit in which current flows instantly over and over, such as a switching circuit or a charging and discharging circuit.

Moreover, if the current flowing in a capacitor is not limited when a capacitor is shorted, joule heat occurs due to internal resistance of the capacitor, the capacitor may burn, and the coating resin or the print board on which it is mounted may be scorched.

From the aspect of stability, it can be said that current limitation that is done by introducing series protective resistance is desirable. However, if high reliability is demanded in a noise limiter or other circuit in which protective resistance cannot be inserted, it is recommended that you use it at no more than 50% to 30% of the rated voltage and provide procedures for avoiding burning and other perils.

(6) Voltage division

If 2 or more tantalum capacitors are connected in series and a voltage that is higher than the rated voltage of each one is applied to both ends, a voltage that is proportional to the capacitor's insulation is applied.

In this case, a voltage higher than the rated voltage may be applied to each capacitor, leading to shorting or other failure. Therefore, avoid series connection as much as possible.

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2. Mounting Methods

This capacitor is designed for surface mounting by soldering iron, various reflow methods, flow, and so on. It is not designed for laser beam soldering.

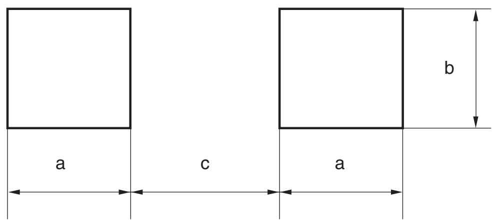
(1) Direct soldering (Do not apply to PS/L series and PS/G series)

Precautions for soldering by means of jet soldering or dipping in a soldering bath are shown below.

(a) Resin for temporary holding

When temporarily holding the capacitor by resin in order to prevent loss when mounting, take care not to use too much resin, since resin may adhere to the board pattern and solderability may become poor.

(b) Pattern design



(Unit: mm)

Case	a	b	c
P	2.2	1.4	0.7
A2, A	2.9	1.7	1.2
B3, B2	3.0	2.8	1.6
C2, C	4.1	2.3	2.4
V, D	5.2	2.9	3.7

Figure 59. Recommended Land Pattern (Direct Soldering)

The above technique is a reference example. When mounting the capacitor by direct soldering, be careful not to make the pattern too small, since solderability may become poor.

(c) Temperature and time

Set the soldering bath temperature and the immersion time to the values below.

Soldering bath temperature ···· 260°C or lower

Immersion time ······················ Up to 5 seconds

However, make the temperature profile as gentle as possible by performing preheating (150°C or lower).

It is important for reliability that heating be performed under conditions of the lowest temperature and shortest time at which the solder contact can be made complete.

(d) Component placement

In mounting by means of jet soldering, the soldering of specific parts of a terminal may be incomplete due to the placement and mounting density of components on a board, the board pattern, and so on. Moreover, since soldering also may be incomplete due to the occurrence of flux gas, be careful about component placement.

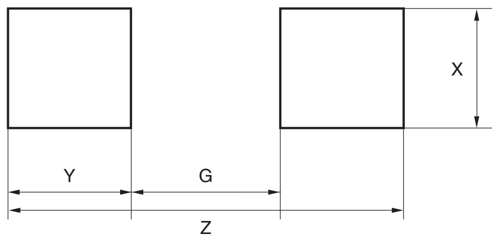
(e) Flux

Use a rosin type as much as possible. Do not use flux that is strongly acidic.

(2) Reflow soldering

Precautions for soldering using a soldering oven or hotplate are shown below.

(a) Pattern design



(Unit: mm)

Case	Gmax.	Zmin.	Xmin.	Y (Reference)
J*	0.65	1.65	0.65	0.50
P2*	1.05	2.05	0.8	0.50
A3*	1.65	3.25	1.1	0.80
J	0.7	2.5	1.0	0.9
P	0.5	2.6	1.2	1.05
A2, A	1.1	3.8	1.5	1.35
B3, B2	1.4	4.1	2.7	1.35
C2, C	2.9	6.9	2.7	2.0
V, D	4.1	8.2	2.9	2.05

* Applies to the F/SV series only (Conforms to EIAJ RC-2371A)

Figure 60. Recommended Land Patterns (Reflow Soldering)

The above dimensions are reference examples. For reflow soldering, be careful not to make the pattern too large; otherwise there may be gaps in component placement or tombstone phenomena.

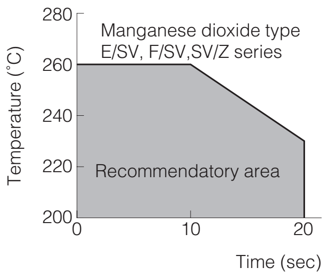
(b) Temperature and time

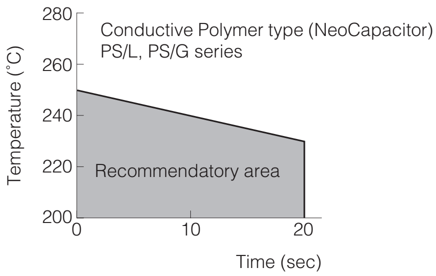
Set the peak temperature and the heating time to the values below.

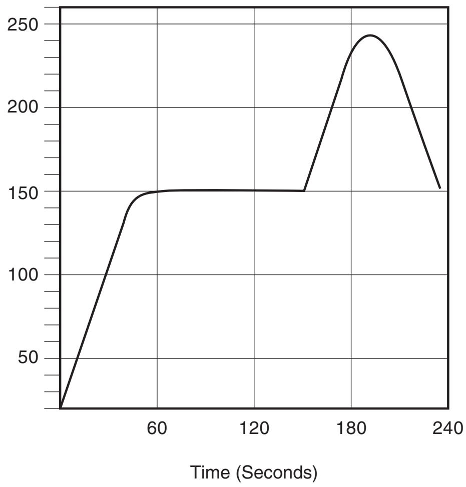
Oven temperature
Temperature on plate ··········· 260°C or lower (PS/L, PS/G series: 240°C or lower)

Heating time ··········· Up to 10 seconds

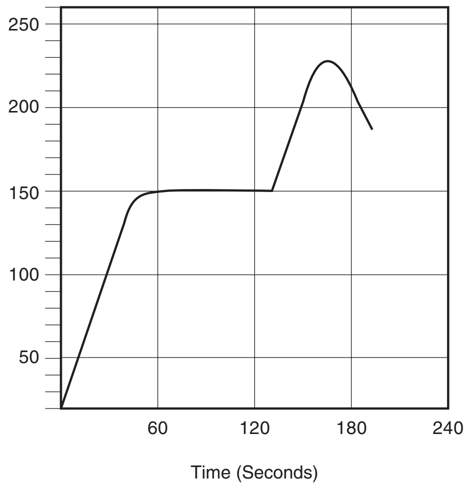
However, make the temperature profile as gentle as possible by performing preheating (150°C or lower). For reflow using infrared or far-infrared rays, be aware that the internal temperature of the component may be higher than the surface temperature.







Recommended conditions
Preheating: 150 to 180°C for 90 seconds
Soldering: 245°C peak
230°C or higher for 20 seconds



Target conditions
Preheating: 150°C for 120 seconds
Soldering: 230°C peak
200°C or higher for 30 seconds

Figure 61. Recommended Temperature Profile

(3) Ironing

The temperature of a soldering iron tip cannot be adequately controlled because of the shape of the iron and the state of heat radiation. Mounting under the conditions below is recommended.

Iron tip temperature ············ 350°C or lower

Contact time ························ For 3 seconds

Iron output ··························· 30 W or lower

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3. Cleaning

Water and various organic solvents are used in flux washing after soldering electronic components. The cleaning techniques, which are immersion cleaning, rinse cleaning, brush cleaning, shower cleaning, vapor cleaning, ultrasonic cleaning,* and others, are used in combination. A wide range of cleaning temperatures from normal temperature to near the boiling point of the cleaning liquid is used. However, cleaning techniques that pursue only the cleaning effect bring about detachment of the seals of electronic components and damage to their appearance. In extreme cases, they also could cause irregularities in function. Accordingly, chip tantalum capacitor flux washing should be performed in the recommended conditions shown below.

[Recommended conditions for flux washing]

(1) Cleaning solvent ··········· Isopropyl alcohol, other polyalcohol solvents

(2) Cleaning technique ······· Shower cleaning, rinse cleaning, vapor cleaning

(3) Cleaning time ················ Up to 5 minutes

* About ultrasonic cleaning

This cleaning technique, which is extremely effective for flux removal, also can cause problems depending on setup conditions. As a result of ultrasonic cleaning tests at NEC TOKIN, it has been confirmed that shearing of external terminals of capacitors occurs when cleaning devices of some makers are used. The cause of this external terminal shearing is thought to be metal fatigue in capacitor terminals caused by ultrasonic waves. To prevent external terminal shearing, there are techniques such as lowering ultrasonic oscillator output and shortening the cleaning time. However, since there are various fluctuation factors such as the ultrasonic oscillator conversion efficiency, cleaning bath transfer efficiency, placement in the cleaning bath, size and quantity of the boards to be cleaned, solid state of the component, and cleaning liquid, it is difficult to uniformly establish recommended cleaning conditions. Accordingly, we ask you to avoid applying ultrasonic cleaning.

If you must apply ultrasonic cleaning, carefully check whether there are no abnormalities under the conditions that are tougher than the actual use conditions beforehand.

Do not apply ultrasonic cleaning when the ambient temperature is close to the boiling point of the cleaning liquid.

If anything is unclear, contact NEC TOKIN.

4. Other

(1) Do not apply excessive vibration or shock to tantalum capacitors.

(2) If you use tantalum capacitors in a highly humid atmosphere, be sure to perform moisture proofing after mounting.

(3) Avoid using the capacitors in an acid or alkali mist.

(4) Since solderability may worsen due to the influence of humidity, store the capacitors at a normal temperature (–5 to +40°C) and normal humidity (40 to 60% RH) so that condensation does not occur.

(5) Avoid applying external stress to tape packing. (Deformation in packing materials influences the performance of auto installation.

5. Precautions Specific to Conductive Polymer Capacitor (NeoCapacitor)

(1) Permissible ripple current

For the permissible ripple current, perform calculations according to the conditions below.

(a) Change due to temperature

At 25°C: Specification in the individual catalog

At 85°C: Specification in the individual catalog × 0.9

At 105°C: Specification in the individual catalog × 0.4

(b) Change due to switching frequency

At 10 kHz: Specification in the individual catalog × 0.75

At 100 kHz: Specification in the individual catalog

At 500 kHz: Specification in the individual catalog × 1.1

At 1 MHz: Specification in the individual catalog × 1.3

(2) Mounting method

Conductive polymer capacitors are designed for various reflow soldering surface mounting methods.

The mounting conditions are basically the same as those for mounting manganese dioxide tantalum capacitors; however the peak temperature at the time of reflow soldering differs.

Atmospheric temperature, temperature on plate: 240°C or lower (Manganese dioxide: 260°C or lower)

Soldering iron solder adjustment conditions are shown in "(3) Ironing" on page 64.

Conductive polymer capacitors are not designed for laser beam mounting, VPS mounting, or flow soldering mounting.

6. When Shorting Occurs

(1) If shorting occurs in a general tantalum capacitor whose electrode material is manganese dioxide, the defect may lead to smoke emission, ignition, or burnout depending on the short-circuit current.

(2) If shorting occurs in a NeoCapacitor whose electrode material is a conductive polymer, the defect may lead to heat generation or smoke emission depending on the short-circuit current.
(A conductive polymer electrode material has the following characteristic: Insulation characteristics in the failure area at the time of shorting are superior to those of manganese dioxide.)

When designing a circuit, follow the contents of this section and make the circuit as redundant as possible.

These precautions for use incorporate contents from a technical report issued by JEITA "Guideline of notabilia for fixed tantalum electrolyte capacitors with solid electrolyte for use in electronic equipment" (RCR2368B) (based on investigations by Japanese tantalum capacitor manufacturers) that NEC TOKIN considers to be important.

PRODUCT SPECIFICATIONS

- **MANGANESE DIOXIDE TANTALUM CAPACITORS**
- **CONDUCTIVE POLYMER TANTALUM CAPACITORS**
- **CONDUCTIVE POLYMER NIOBIUM CAPACITORS**

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1. Manganese Dioxide Tantalum Capacitors

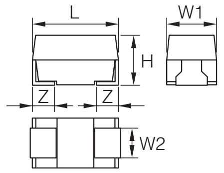
E/SV Series

■ FEATURES

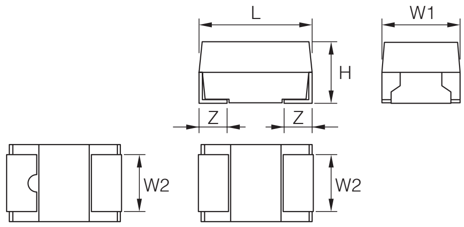
- Lead-free Type. In conformity to RoHS.
- Offer a range of small, high-capacity models.
- Succeed to the latest technology plus outstanding performance.

■ DIMENSIONS [mm]

[J, P, A2, A cases]

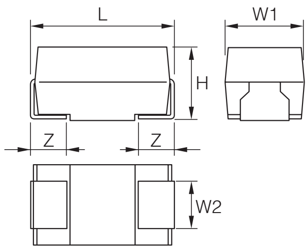


[B3, B2 cases]



B2 case　B3 case

[C2, C, V, D cases]



(Unit: mm)

Case Code	EIA code	L	W_1	W_2	H	Z
J	–	1.6 ± 0.1	0.8 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.3 ± 0.15
P	2012	2.0 ± 0.2	1.25 ± 0.2	0.9 ± 0.1	1.1 ± 0.1	0.5 ± 0.1
A2 (U)	3216L	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	1.1 ± 0.1	0.8 ± 0.2
A	3216	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	1.6 ± 0.2	0.8 ± 0.2
B3 (W)	3528L	3.5 ± 0.2	2.8 ± 0.2	2.2 ± 0.1	1.1 ± 0.1	0.8 ± 0.2
B2 (S)	3528	3.5 ± 0.2	2.8 ± 0.2	2.2 ± 0.1	1.9 ± 0.2	0.8 ± 0.2
C2	–	6.0 ± 0.2	3.2 ± 0.2	2.2 ± 0.1	1.4 ± 0.1	1.3 ± 0.2
C	6032	6.0 ± 0.2	3.2 ± 0.2	2.2 ± 0.1	2.5 ± 0.2	1.3 ± 0.2
V	–	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	1.9 ± 0.1	1.3 ± 0.2
D	7343	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	2.8 ± 0.2	1.3 ± 0.2

■ STANDARD C-V VALUE REFERENCE BY CASE CODE

μF	U_R	2.5 V 0E	4 V 0G	6.3 V 0J	10 V 1A	16 V 1C	20 V 1D	25 V 1E	35 V 1V
0.47	474					P	A2	A	A
0.68	684					P	A2	A	A
1.0	105				P	J, P	A2	P, A2, A	A2, A
1.5	155			P	J, P	A	A2		A
2.2	225			J	J, P	P, A2, A, [J]	P, A2, A	A, [P]	A, B2
3.3	335		P	J	P, A2	A2, A	A, B3	A	B2, [B3]
4.7	475			J, P, A	J, P, A2, A	A2, A	A2, A, B3, B2	B3, B2, [A2]	C
6.8	685		J	J, P, A2	A2, A	A, B3	B2		C
10	106	J	J, P	J, P, A2, A	P, A2, A, B2	A, B3, B2	B2	C, [B2]	C, D
15	156		P	P, A2, A	B3, [P]	B2, [A]	C	C	D
22	226	P, A2	P, A2, A	P, A2, A, B3, B2	A, B3, B2, [A2]	B3, B2, C	C2, C, D	D	
33	336	P, A2	P, A2, A	A, B3, [A2]	B3, B2, [A]	C2, C, [B2]	D	D	
47	476	P, A2, A	P, A2, A, B3	A, B3, B2, C	B2, C2, C, [B3]	C, D	D	[D]	
68	686	A	A, B3	B2, C2	B2, C2, C	C, D			
100	107	B3, B2	A, B3, B2, C2	B2, C2, C, [B3]	C, V, D, [C2]	D			
150	157	A, B3, C2	B2, C2	C	V, D				
220	227	B2, C2	B2, C	C, V, D	D				
330	337	B2, C	C, V	D					
470	477	C, D	D	D					
680	687		D						

[ ]: Under development

■ PART NUMBER SYSTEM

[Bulk]

ESV A 0J 106 M

- M — Capacitance tolerance (M: ±20%, K: ±10%)
- 106 — Capacitance (pF) (The first two digits represent significant figures. The third digit specifies number of zeros to follow.)
- 0J — DC rated voltage in volts (0E: 2.5 V, 0G: 4 V, 0J: 6.3 V, 1A: 10 V, 1C: 16 V, 1D: 20 V, 1E: 25 V, 1V: 35 V)
- A — Case code
- ESV — E/SV Series

[Tape and Reel]

TE ESVA0J106M 8 R

- R — Packing orientation (R: Cathode on the side of sprocket hole)
- 8 — Tape width (8: 8 mm (J, P, A2, A, B3, B2 case), 12: 12 mm (C2, C, V, D case))
- ESVA0J106M — Part number of bulk
- TE — Tape and reel (TE : 180 mmϕ reel)

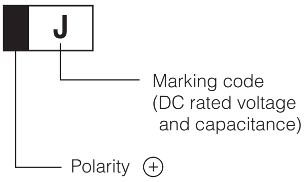
TL ESVA0J106M 8 R E

- TL — Tape and reel (TL : 330 mmϕ reel)
- E — Indicates 330mmϕ reel

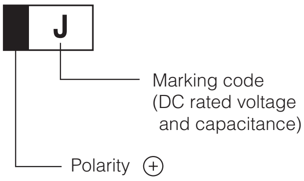
■ MARKINGS

The standard marking shows capacitance, DC rated voltage, and polarity.

[J case] (ex. 4.7 μF / 6.3 V)



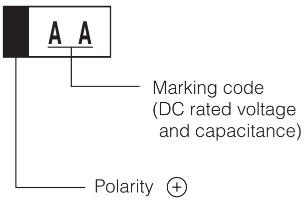
[J case] (ex. 4.7 μF / 6.3 V)



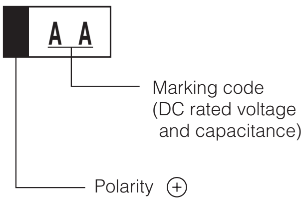
[J case marking code]

U_R / μF	2.5 V	4 V	6.3 V	10 V	16 V
1.0					Ɔ
1.5				∀	
2.2			ſ	ᐊ	
3.3			ᒋ		
4.7			J	ᐅ	
6.8		G	ᓚ		
10	e	⅁	ſ̄		

[P case] (ex. 1 μF / 10 V)



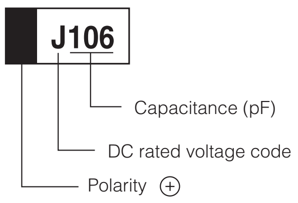
[P case] (ex. 1 μF / 10 V)



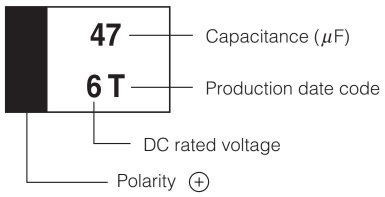
[P case marking code]

U_R / μF		4 V	6.3 V	10 V	16 V	20V	25V
0.47					CS		
0.68					CW		
1				AA	CA		EA
1.5			JE	AE			
2.2				AJ	CJ	DJ	
3.3		GN		AN			
4.7			JS	AS			
6.8			JW				
10		GĀ	JĀ	AĀ			
15		GĒ	JĒ				
22	eJ̄	GJ̄	JJ̄				
33	eN̄	GN̄					
47	eS̄	GS̄					

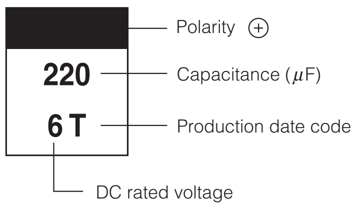
[A2, A cases] (ex. 10 μF / 6.3 V)



[B3, B2 cases] (ex. 47 μF / 6.3 V)



[C2, C, V, D cases] (ex. 220 μF / 6.3 V)



[P, A2, A, cases DC rated voltage code]

Code	e	G	J	A	C	D	E	V
Rated Voltage	2.5 V	4 V	6.3 V	10 V	16 V	20 V	25 V	35 V

[B3, B2, C2, C, V, D cases production date code]

Y \ M	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2003	a	b	c	d	e	f	g	h	j	k	l	m
2004	n	p	q	r	s	t	u	v	w	x	y	z
2005	A	B	C	D	E	F	G	H	J	K	L	M
2006	N	P	Q	R	S	T	U	V	W	X	Y	Z

Note: Production date code will repeat beginning in 2007.

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■ PERFORMANCE CHARACTERISTICS

Test Conditions: Conform to IEC 60384-1

<table>
<tr><th colspan="2">Item</th><th colspan="8">Performance</th><th>Test Conditions
(IEC 60384-1)</th></tr>
<tr><td colspan="2">Operating temperature range</td><td colspan="8">–55°C to +125°C</td><td>Derated voltage if 85°C is exceeded</td></tr>
<tr><td colspan="2">Rated voltage</td><td>2.5V</td><td>4V</td><td>6.3V</td><td>10V</td><td>16V</td><td>20V</td><td>25V</td><td>35V</td><td>at 85°C</td></tr>
<tr><td colspan="2">Derated voltage</td><td>1.6V</td><td>2.5V</td><td>4V</td><td>6.3V</td><td>10V</td><td>13V</td><td>16V</td><td>22V</td><td>at 125°C</td></tr>
<tr><td colspan="2">Surge voltage</td><td>3.3V</td><td>5.2V</td><td>8V</td><td>13V</td><td>20V</td><td>26V</td><td>33V</td><td>46V</td><td>at 85°C</td></tr>
<tr><td colspan="2">Capacitance</td><td colspan="8">0.47 μF to 680 μF</td><td rowspan="2">at 120 Hz (As per 4.7)</td></tr>
<tr><td colspan="2">Capacitance tolerance</td><td colspan="8">±20% for P or J case, ±20% or ±10% for cases other than P and J</td></tr>
<tr><td colspan="2">Leakage current</td><td colspan="8">Less than the value of 0.01C • V(μA) or 0.5 μA, whichever is greater</td><td>5 minutes after rated voltage application (As per 4.9)</td></tr>
<tr><td colspan="2">Dissipation factor</td><td colspan="8">According to individual catalog</td><td>at 120 Hz (As per 4.8)</td></tr>
<tr><td colspan="2">Equivalent series resistance</td><td colspan="8">According to individual catalog</td><td>at 100 kHz</td></tr>
<tr><td colspan="2"></td><td colspan="3">Capacitance change</td><td colspan="3">DF</td><td colspan="2">Leakage current</td><td></td></tr>
<tr><td colspan="2">Surge</td><td colspan="3">±5% to ±20%
For details, see individual catalog</td><td colspan="3">Shall not exceed the initial requirements</td><td colspan="2">Shall not exceed the initial requirements</td><td>(As per 4.26)</td></tr>
<tr><td rowspan="3">Characteristics at high and low temperature</td><td>–55°C</td><td colspan="3"><P or J> <Cases other than P and J>
0% 0%
–20% –12%</td><td colspan="3">Refer to individual catalog</td><td colspan="2">———</td><td rowspan="3">(As per 4.24)</td></tr>
<tr><td>+85°C</td><td colspan="3">+20% +12%
0% 0%</td><td colspan="3">Shall not exceed the initial requirements</td><td colspan="2">Less than the value of 0.1C V(μA) or 5 μA, whichever is greater</td></tr>
<tr><td>+125°C</td><td colspan="3">+20% +15%
0% 0%</td><td colspan="3">Refer to individual catalog</td><td colspan="2">Less than the value of 0.125C V(μA) or 6.25 μA, whichever is greater</td></tr>
<tr><td colspan="2">Temperature cycle</td><td colspan="3">±5% to ±20%
For details, see individual catalog</td><td colspan="3">Shall not exceed the initial requirements</td><td colspan="2">Shall not exceed the initial requirements</td><td>–55°C to +20°C to +125°C
5 cycles (As per 4.21)</td></tr>
<tr><td colspan="2">Resistance to soldering heat</td><td colspan="3">±5% to ±20%
For details, see individual catalog</td><td colspan="3">Shall not exceed the initial requirements</td><td colspan="2">Shall not exceed the initial requirements</td><td>Solder dip: 260°C, 5sec
Reflow: 260°C,10sec</td></tr>
<tr><td colspan="2">Damp heat</td><td colspan="3">±5% to ±20%
For details, see individual catalog</td><td colspan="3">Shall not exceed 150% of the initial requirements</td><td colspan="2">Shall not exceed the initial requirements</td><td>40°C
90 to 95% RH
500 hours (As per 4.22)</td></tr>
<tr><td colspan="2">Endurance</td><td colspan="3">±10% to ±20%
For details, see individual catalog</td><td colspan="3">Shall not exceed the initial requirements</td><td colspan="2"><P or J case>
Shall not exceed 200% of the initial requirements
<Case other than P and J>
Shall not exceed 125% of the initial requirements</td><td>85°C: Rated voltage application
125°C: Derated voltage application
(As per 4.23)</td></tr>
<tr><td colspan="2">Failure rate</td><td colspan="8">λ_0 = 1%/1,000 hour</td><td>85°C: Rated voltage application
125°C: Derated voltage application</td></tr>
<tr><td colspan="2">Terminal strength</td><td colspan="8">Visual: There shall be no evidence of mechanical damage</td><td>After board mounting, apply 4.9 N force in 2 directions</td></tr>
<tr><td colspan="2">Other</td><td colspan="8">Conforms to IEC 60384-1</td><td>Conforms to IEC 60384-1</td></tr>
</table>

Reference: Derated voltage (85 to 120°C)

$$[U_T] = [U_R] - \frac{[U_R]-[U_C]}{40}(T-85)$$

$[U_T]$: Derated voltage at operating temperature
$[U_R]$: Rated voltage
$[U_C]$: Derated voltage at 125°C
T: Ambient temperature

SV/Z Series

■ FEATURES

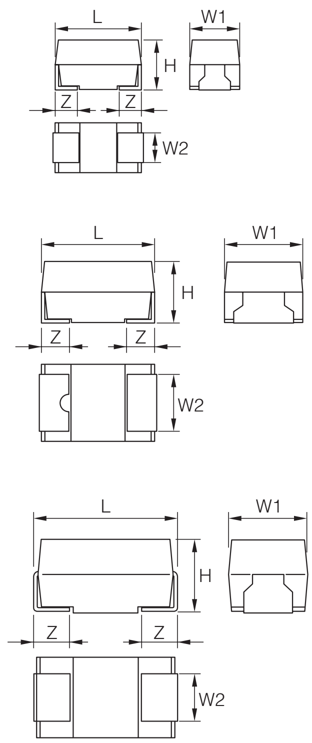
- Lead-free Type. In conformity to RoHs.
- Low-ESR Type.
- For decoupling with CPU, for absorbing the noise.
- Same dimension as E/SV series.

■ DIMENSIONS [mm]

[A case]

[B2 case]

[C, V, D cases]



(Unit: mm)

Case Code	EIA code	L	W_1	W_2	H	Z
A	3216	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	1.6 ± 0.2	0.8 ± 0.2
B2	3528	3.5 ± 0.2	2.8 ± 0.2	2.2 ± 0.1	1.9 ± 0.2	0.8 ± 0.2
C	6032	6.0 ± 0.2	3.2 ± 0.2	2.2 ± 0.1	2.5 ± 0.2	1.3 ± 0.2
V	7343L	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	1.9 ± 0.1	1.3 ± 0.2
D	7343	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	2.8 ± 0.2	1.3 ± 0.2

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■ STANDARD C-V VALUE REFERENCE BY CASE CODE

μF		4 V 0G	6.3 V 0J	10 V 1A	16 V 1C	20 V 1D	25 V 1E	35 V 1V
6.8	685						C 600	C 600
10	106		A 800	B2 600				D 300
15	156						D 250	D 300
22	226		B2 800				D 200	
33	336					D 200		
47	476			C 300	D 150	D 150		
68	686			B2 250	C, D 200, 150			
100	107		C, D 150, 150	C, V, D 125, 150, 100	D 100			
150	157		C, D 125, 100	V, D 150, 100				
220	227	D 100	V, D 150, 100	D 100				
330	337	V, D 150, 100	D 100					

Number: ESR (mΩ)

■ PART NUMBER SYSTEM

[Bulk]

SVZ D 1C 107 M

- M — Capacitance tolerance (M: ±20%)
- 107 — Capacitance (pF) (The first two digits represent significant figures. The third digit specifies number of zeros to follow.)
- 1C — DC rated voltage in volts (0G: 4 V, 0J: 6.3 V, 1A: 10 V, 1C: 16 V, 1D: 20 V, 1E: 25 V, 1V: 35 V)
- D — Case code
- SVZ — SV/Z Series

[Tape and Reel]

TE SVZD1C107M 12 R

- R — Packing orientation (R: Cathode on the side of sprocket hole)
- 12 — Tape width (8: 8 mm (A, B2 case), 12: 12 mm (C, V, D cases))
- SVZD1C107M — Part number of bulk
- TE — Tape and reel (TE: 180mm ϕ reel)

TL SVZD1C107M 12 R E

- TL — Tape and reel (TL: 330mm ϕ reel)
- E — Indicates 330mm ϕ reel

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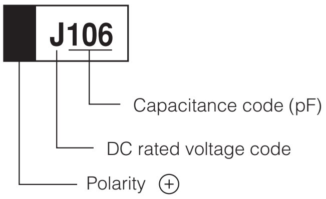
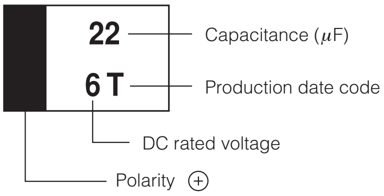
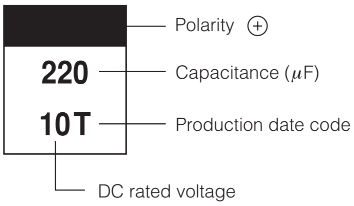
[A case] (ex. 10 μF/6.3 V)



[B2 case] (ex. 22 μF/6.3 V)



[C, V, D case] (ex. 220 μF/10 V)



[DC rated voltage code]

Code	G	J	A	C	D	E	V
Rated Voltage	4 V	6.3 V	10 V	16 V	20 V	25 V	35 V

[B2, C, V, D cases production date code]

Y \ M	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2003	a	b	c	d	e	f	g	h	j	k	l	m
2004	n	p	q	r	s	t	u	v	w	x	y	z
2005	A	B	C	D	E	F	G	H	J	K	L	M
2006	N	P	Q	R	S	T	U	V	W	X	Y	Z

Note: Production date code will resume beginning in 2007.

■ PERFORMANCE CHARACTERISTICS

Test Conditions: Conform to IEC 60384-1

Item	Performance							Test Conditions (IEC 60384-1)
Operating temperature range	–55°C to +125°C							Derated voltage if 85°C is exceeded
Rated voltage	4V	6.3V	10V	16V	20V	25V	35V	at 85°C
Derated voltage	2.5V	4V	6.3V	10V	13V	16V	22V	at 125°C
Surge voltage	5.2V	8V	13V	20V	26V	33V	46V	at 85°C
Capacitance	6.8 μF to 330 μF							at 120 Hz (As per 4.7)
Capacitance tolerance	±20%							
Leakage current	Less than the value of 0.01C • V(μA) or 0.5 μA, whichever is greater							5 minutes after rated voltage application (As per 4.9)
Dissipation factor	According to individual catalog							at 120 Hz (As per 4.8)
Equivalent series resistance	According to individual catalog							at 100 kHz

Item		Capacitance change	DF	Leakage current	Test Conditions
Surge		±5% to ±20% For details, see individual catalog	Shall not exceed the initial requirements	Shall not exceed the initial requirements	(As per 4.26)
Characteristics at high and low temperature	–55°C	0% –12%	Refer to individual catalog	———	(As per 4.24)
	+85°C	+12% 0%	Shall not exceed the initial requirements	Less than the value of 0.1C V(μA) or 5 μA, whichever is greater	
	+125°C	+15% 0%	Refer to individual catalog	Less than the value of 0.125C V(μA) or 6.25 μA, whichever is greater	
Temperature cycle		±5% to ±12% For details, see individual catalog	Shall not exceed the initial requirements	Shall not exceed the initial requirements	–55°C to +20°C to +125°C 5 cycles (As per 4.21)
Resistance to soldering heat		±5% to ±12% For details, see individual catalog	Shall not exceed the initial requirements	Shall not exceed the initial requirements	Solder dip: 260°C, 5sec Reflow: 260°C, 10sec
Damp heat		±5% to ±12% For details, see individual catalog	Shall not exceed 150% of the initial requirements	Shall not exceed the initial requirements	40°C 90 to 95% RH 500 hours (As per 4.22)
Endurance		±10% to ±12% For details, see individual catalog	Shall not exceed the initial requirements	Shall no t exceed 125% of the initial requirements	85°C: Rated voltage application 125°C: Derated voltage application 2,000 hrs (As per 4.23)
Failure rate		λ_0 = 1%/1,000 hour			85°C: Rated voltage application 125°C: Derated voltage application 2,000 hrs (As per 4.23)
Terminal strength		Visual: There shall be no evidence of mechanical damage			After board mounting, apply 4.9 N force in 2 directions
Other		Conforms to IEC 60384-1			Conforms to IEC 60384-1

Reference: Derated voltage (85 to 120°C)

$$[U_T] = [U_R] - \frac{[U_R]-[U_C]}{40}(T-85)$$

$[U_T]$: Derated voltage at operating temperature
$[U_R]$: Rated voltage
$[U_C]$: Derated voltage at 125°C
T: Ambient temperature

2006.03.24 P0622EDTM01VOL02E

F/SV Series

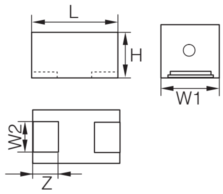
New Product

■ FEATURE

- **Lead-free type. In conformity to RoHs.**
- **Face down terminal**
- **The low-profile of height 0.85mm Max and large capacitance of 47μF available in 1608 size.**
- **Enable fillet bonding**

■ DIMENSIONS

[J Case]



(Unit: mm)

Case Code	L	W_1	W_2	H	Z
J	1.6 ± 0.1	0.85 ± 0.1	0.65 ± 0.1	0.8 ± 0.1	0.5 ± 0.1
P2 *	2.0 ± 0.1	1.25 ± 0.1	0.9 ± 0.1	0.9 ± 0.1	0.55 ± 0.1
A3 *	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	0.9 ± 0.1	0.8 ± 0.2

* Under development

■ STANDARD C-V VALUE REFERENCE BY CASE CODE

UR: Rated voltage

μF \ U_R		2.5 0E	4 0G	6.3 0J	10 1A	16 1C	20 1D	25 1E
1							[J]	
1.5								
2.2								[P2]
3.3								
4.7	475					[J]	[P2]	[A3]
6.8	685							
10	106				[J]	[P2]	[A3]	
15	156							
22	226			[J]	[P2]	[A3]		
33	336		J	[P2]				
47	476	J		[P2]	[A3]			
68	686		[P2]					
100	107	[P2]	[P2]	[A3]				
220	227	[A3]	[A3]					

[ ]: Under development

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■ PART NUMBER SYSTEM

[Bulk]

FSV J 0E 476 M

- M — Capacitance tolerance (M: ±20%)
- 476 — Capacitance (in pF) (The first two digits represent significant figures. The third digit specifies number of zeros to follow.)
- 0E — Rated voltage
- J — Case code
- FSV — F/SV Series

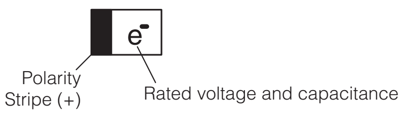
[Tape and Reel]

TE FSVJ0E476M 8 R

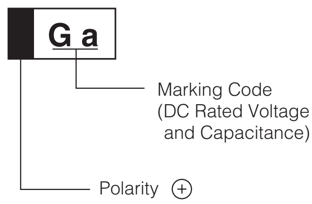
- R — Packing orientation (R: Cathode on the side of sprocket hole)
- 8 — Tape width (8: 8 mm)
- FSVJ0E476M — Part number of bulk
- TE — Tape and reel packing

■ MARKINGS

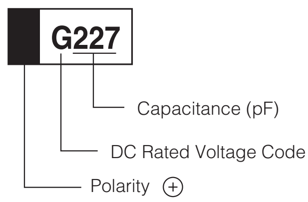
[J case]



[P2 case] Under development



[A3 case] Under development



[Rated voltage and capacitance]

[Rated Marking code] UR: Rated voltage

UR		2.5	4	6.3	10	16	20
μF		0E	0G	0J	1A	1C	1D
1.0	105						[ᗡ‾]
3.3	335						
2.2	225						
3.3	335						
4.7	475					[Ɔ‾]	
6.8	685						
10	106				[ᗆ‾]		
15	156						
22	226			[J‾]			
33	336		G‾				
47	476	e‾					

[ ] :Under development

[P2 case Marking code] UR: Rated voltage

UR		2.5	4	6.3	10	16	20	25
μF		0E	0G	0J	1A	1C	1D	1E
2.2	225							EJ
3.3	335							
4.7	475						DS	
6.8	685							
10	106					C$\overline{A}$		
15	156							
22	226				A$\overline{J}$			
33	336			J$\overline{N}$				
47	476			J$\overline{S}$				
68	686		G$\overline{W}$					
100	107	ea	Ga					

[A3 case DC Rated Voltage code]

Code	e	G	J	A	C	D	E
Raged Voltage	2.5 V	4 V	6.3 V	10 V	16 V	20 V	25 V

■ PERFORMANCE CHARACTERISTICS

Test Conditions: Conform to IEC 60384-1

ITEM	PERFORMANCE							TEST CONDITION
Operating temperature	-55°C to +125°C							Derated voltage if 85°C is exceeded
Rated voltage (V.dc)	2.5V	4V	[6.3V]	[10V]	[16V]	[20V]	[25V]	at 85°C
Derated voltage (V.dc)	1.6V	2.5V	[4V]	[6.3V]	[10V]	[13V]	[16V]	at 125°C
Surge voltage (V.dc)	3.3V	5.2V	[8V]	[13V]	[20V]	[26V]	[33V]	at 85°C
Capacitance	33 µF to 47 µF							at 120 Hz
Capacitance tolerance	±20%							
DC Leakage Current (L.C)	0.01C • V(µA) or 0.5µA , whichever is greater							Voltage: Rated voltage for 5min.
Dissipation Factor	Refer to Standard Ratings							at 120 Hz
Equivalent Series Resistance	Refer to Standard Ratings							at 100 kHz

ITEM		Capacitance change	DF(%)	L.C	TEST CONDITION
Surge voltage test		Refer to Standard Ratings	Lower than initial specification	Lower than initial specification	Temperature: 85±2°C Applied voltage: Surge voltage Series resistance: 33 ohm Duration of surge: 30±5 sec Time between surge: 5.5min. Number of cycle: 1000
Characteristic at high and low temperature	-55°C	Not to exceed -20%	Refer to Standard Ratings	———	Step 1: 25±2°C Step 2: -55^{0}_{-3}°C Step 3: 25±2°C Step 4: 125^{0}_{-3}°C
	+85°C	Not to exceed +20%	Lower than initial specification	0.1C•V(µA) or 5µA, whichever is greater	
	+125°C	Not to exceed +20%	Refer to Standard Ratings	0.125C•V(µA) or 6.25µA, whichever is greater	
Rapid change of temperature		Refer to Standard Ratings	Lower than initial specification	Lower than initial specification	Parts shall be temperature cycled over a temperature range of -55 to +125°C, five times continuously as follow. Step 1: -55^{0}_{-3} °C, 30±3min. Step 2: room temp. , 10 to 15min. Step 3: 125^{0}_{-3}°C, 30±3min. Step 4: room temp, 10 to 15min.
Resistance to Soldering heat		Refer to Standard Ratings	Lower than initial specification	Lower than initial specification	solder dip: 260°C, 5sec solder reflow: 260°C, 10sec
Damp heat		Refer to Standard Ratings	Lower than 1.5 times initial specification	Lower than initial specification	at 40°C at 90 to 95% RH 500 hour
Endurance		Refer to Standard Ratings	Lower than initial specification	Lower than 2 times initial specification	at 85°C: Rated voltage at 125°C: Derated voltage 2000 hour
Failure Rate		λ_0=1%/1000 hour			at 85°C: Rated voltage at 125°C: Derated voltage 2000 hour
Terminal Strength		Visual: There shall be no evidence of mechanical damage			Strength: 4.9N Time: 10±0.5sec. (two directions)

[ ]: Under development

Reference: Derated voltage (85 to 120°C)

$$[U_T] = [U_R] - \frac{[U_R]-[U_C]}{40}(T-85)$$

[U_T]: Derated voltage at operating temperature
[U_R]: Rated voltage
[U_C]: Derated voltage at 125°C
T: Ambient temperature

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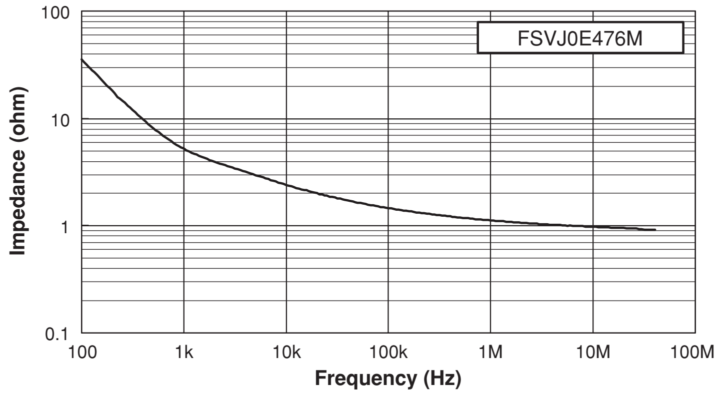
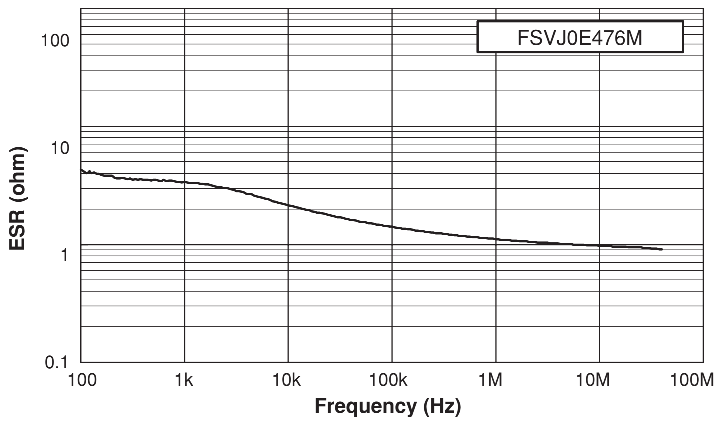
■ CHARACTERISTICS (reference)

Impedance-frequency characteristics



ESR-frequency characteristics



2. Conductive Polymer Tantalum Capacitor

NeoCapacitor

■ Overview

The NeoCapacitor is a tantalum capacitor whose cathode layer is a conductive polymer.

The use of a highly conductive polymer instead of the conventional manganese dioxide has led to a significant reduction in equivalent series resistance (ESR). The reduction not only makes it possible to make the permissible ripple current large, but also leads to highly effective noise absorption in high frequency circuits. Accordingly, the NeoCapacitor has become widely used in various multimedia fields.

At first, two types of NeoCapacitor--the PS/N series (85°C guaranteed) and the PS/M series (105°C guaranteed)--were released. Polypyrrole is used as the conductive polymer in these series. Subsequently, we developed the PS/L series (105°C guaranteed)--our existing anchor product--whose ESR is lower due to a charge in the conductive polymer from polypyrrole to polyvinylene. Moreover, 9 mΩ or less ultra low ESR line has been lined up as the PS/G series. Of new designs, the PS/L and PS/G series are recommended. The PS/N series has already been discontinued and the PS/M series is in the process of being discontinued.

■ Features

● **Superior noise absorption due to low ESR characteristics**

With a conductive lower ESR than the conventional manganese tantalum capacitors. We are continuously trying to develop a NeoCapacitor with ever lower ESR. The existing NeoCapacitor is highly effective in absorbing the higher levels of noise emitted by recent high-performance equipment.

● **Abundant case sizes including ultra small size**

Abundant case sizes from the industry's smallest J case to the large size D case are offered. We offer the most diversified line of small-sized products in the industry (B2 and smaller cases). The NeoCapacitor is a necessity in mobile phones, PDAs, notebook PCs, and other portable equipment.

● **Small size and large capacity**

Compared to multilayer ceramic capacitors and aluminum electrolytic capacitors, NeoCapacitors are small in size and have a large capacity. They also contribute to equipment down-sizing.

● **Smoke and flame retardant**

If current flows in a tiny defective portion at a stage that could lead to failure, cathode layer insulation occurs quickly due to an advantage of the conductive polymer. This means that the NeoCapacitor's construction makes it hard for failure to occur.

■ Applications

- PCs (MPU voltage fluctuation suppression, power supply energy supply assistance)
- Mobile phones (RF block energy drop suppression, display block voltage drop assistance)
- D/D converters (for smoothing), videocameras, digital cameras, portable CDs, HDDs, CD-ROMs, digital portable equipment, and game machines

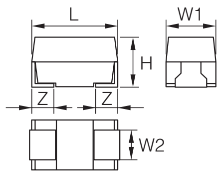
PS/L Series

■ FEATURES

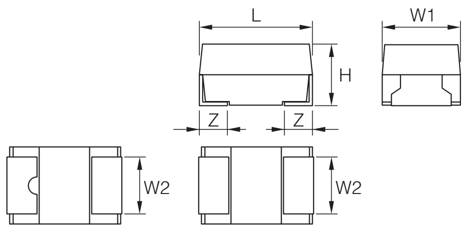
- Lead-free Type. In conformity to RoHs.
- Ultra-Low ESR
- Same Dimension as E/SV series

■ DIMENSIONS [mm]

[J, P, A2, A cases]

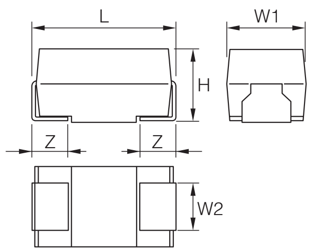


[B3, B2 cases]



B2 case **B3 case**

[C2, C, V, D cases]



(Unit: mm)

Case Code	EIA code	L	W_1	W_2	H	Z
J	–	1.6 ± 0.1	0.8 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.3 ± 0.15
P	2012	2.0 ± 0.2	1.25 ± 0.2	0.9 ± 0.1	1.1 ± 0.1	0.5 ± 0.1
A2 (U)	3216L	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	1.1 ± 0.1	0.8 ± 0.2
A	3216	3.2 ± 0.2	1.6 ± 0.2	1.2 ± 0.1	1.6 ± 0.2	0.8 ± 0.2
B3 (W)	3528L	3.5 ± 0.2	2.8 ± 0.2	2.2 ± 0.1	1.1 ± 0.1	0.8 ± 0.2
B2 (S)	3528	3.5 ± 0.2	2.8 ± 0.2	2.2 ± 0.1	1.9 ± 0.2	0.8 ± 0.2
C2	–	6.0 ± 0.2	3.2 ± 0.2	2.2 ± 0.1	1.4 ± 0.1	1.3 ± 0.2
C	6032	6.0 ± 0.2	3.2 ± 0.2	2.2 ± 0.1	2.5 ± 0.2	1.3 ± 0.2
V	7343L	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	1.9 ± 0.1	1.3 ± 0.2
D	7343	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	2.8 ± 0.2	1.3 ± 0.2

■ STANDARD C-V VALUE REFERENCE BY CASE CODE

μF	UR	2.5 V 0E	4 V 0G	6.3 V 0J	10 V 1A	16 V 1C	20V 1D
2.2	225			J	J		
3.3	335			J, P	A	A	
4.7	475			J, P	A2, A	B2	
6.8	685			P, A	A, B2	B2	
10	106		J, P, A	P, A2, A	A2, A, B2	B2	
15	156			A2, A, B2	B2, C		
22	226	P	P, A2, B2	A2, A, B3, B2	B3, B2, C	[C2(70)]	[V(80)]
33	336		A	A, B3, B2	B3, B2, C2, C	[V(70)]	[V(70)]
47	476		A, B3	B3, B2, C2, C	B2, C2, C, V, D	D, [V(70)]	
68	686		C2, C	B2, C2, C	V, D, [C(100/55)]		
100	107	B3	B3, B2, C2	B2, C, [C2(70)]	V, D, [C(100/55)]		
150	157		B2, C	C, V, D, [C(18)]	D		
220	227	B2	C, V, D, [B2(45)]	V, D	D		
330	337	C, V, [B2(45)], V, [C(18)]	D, [V(12)]	D			
470	477	V	D				
680	687	D	D				
1000	108	D					

[ ]: Under development-specification to be determined. Numeral: ESR (mΩ) at 100 kHz

■ PART NUMBER SYSTEM

[Bulk]

PSL D 0J 337 M (25)

- (25) — Special numbering for ESR (ex. (25) shows 25 mΩ)
- M — Capacitance tolerance (M: ±20%)
- 337 — Capacitance (pF) (The first two digits represent significant figures. The third digit specifies number of zeros to follow.)
- 0J — DC rated voltage in volts (0E: 2.5 V, 0G: 4 V, 0J: 6.3 V, 1A: 10 V, 1C: 16 V)
- D — Case code
- PSL — PS/L Series

[Tape and Reel]

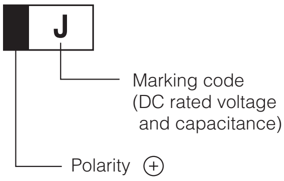
TE PSLD0J337M 12 R

- R — Packing orientation (R: Cathode on the side of sprocket hole)
- 12 — Tape width (8: 8 mm (J, P, A2, A, B3, B2 case) 12: 12 mm (C2, C, V, D cases))
- PSLD0J337M — Part number of bulk
- TE — Tape and reel (TE: 180mm φ reel)

TL PSLD0J337M 12 R E

- TL — Tape and reel (TL: 330mm φ reel)
- E — Indicates 330mm φ reel

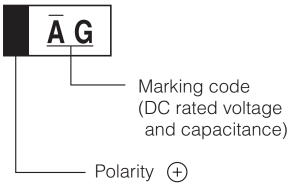
[J case] (ex. 4.7 µF/6.3 V)



[J case marking code]

µF \ U_R	4 V	6.3 V	10 V
2.2		ſ	∢
3.3		ᑐ	
4.7		J	
6.8			
10	ᘓ		

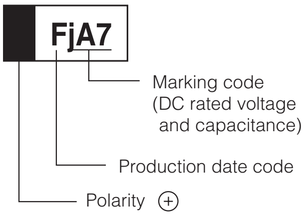
[P case] (ex. 10 µF/4 V)



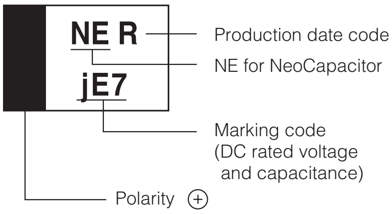
[P case marking code]

µF \ U_R	2.5V	4 V	6.3 V	10 V
3.3			NJ	
4.7			SJ	
6.8			WJ	
10		$\overline{A}$G	$\overline{A}$J	
15				
22	$\overline{J}$e	$\overline{J}$G		

[A2, A cases] (ex. 10 µF/6.3 V)



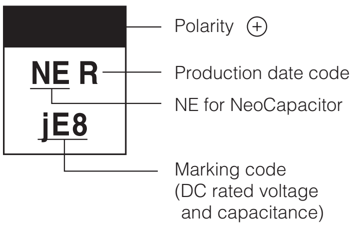
[B3, B2 cases] (ex. 15 µF/6.3 V)



[A2, A, B3, B2, C2, C, V, D cases marking code]

µF \ U_R		2.5 V	4 V	6.3 V	10 V	16 V	20V
		e	g	j	A	C	D
3.3	N6				AN6	CN6	
4.7	S6				AS6	CS6	
6.8	W6			jW6	AW6	CW6	
10	A7		gA7	jA7	AA7	CA7	
15	W7			jE7	AE7		
22	J7		gJ7	jJ7	AJ7		[DJ7]
33	N7		gN7	jN7	AN7		[DN7}
47	S7		gS7	jS7	AS7	CS7	
68	W7		gW7	jW7	AW7		
100	A8	eA8	gA8	jA8	AA8		
150	E8		gE8	jE8	AE8		
220	J8	eJ8	gJ8	jJ8	AJ8		
330	N8	eN8	gN8	jN8			
470	S8	eS8	gS8				
680	W8	eW8	gW8				
1000	A9	eA9					

[C2, C, D cases] (ex. 150 µF/6.3 V)



[A2, A, B3, B2, C2, C, V, D cases production date code]

Y \ M	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2003	a	b	c	d	e	f	g	h	j	k	l	m
2004	n	p	q	r	s	t	u	v	w	x	y	z
2005	A	B	C	D	E	F	G	H	J	K	L	M
2006	N	P	Q	R	S	T	U	V	W	X	Y	Z

Note: Production date code will resume beginning in 2007.

■ PERFORMANCE CHARACTERISTICS

Test Conditions: Conform to IEC 60384-1

Item		Performance						Test Conditions (IEC 60384-1)
Operating temperature range		–55°C to +105°C						Derated voltage if 85°C is exceeded
Rated voltage		2.5V	4V	6.3V	10V	16V	[20V]	at 85°C
Derated voltage		2V	3.3V	5V	8V	12.8V	[16V]	at 105°C
Surge voltage		3.3V	5.2V	8V	13V	20V	[26V]	at 85°C
Capacitance		2.2 μF to 1000 μF						at 120 Hz (As per 4.7)
Capacitance tolerance		±20%						
Leakage current		Less than the value of 0.1C • V(μA) or 3μA (J case:10μA) , whichever is greater						5 minutes after rated voltage application (As per 4.9)
Dissipation factor		According to individual catalog						at 120 Hz (As per 4.8)
Equivalent series resistance		According to individual catalog						at 100 kHz
		Capacitance change		DF		Leakage current		
Surge		Within ±20%		Shall not exceed the initial requirements		Shall not exceed the initial requirements		(As per 4.26)
Characteristics at high and low temperature	–55°C	0 to –20%		Shall not exceed the initial requirements		———		(As per 4.24)
	+105°C	0 to +50%		Shall not exceed 150% of the initial requirements		Shall not exceed 10 times of the initial requirements		
Temperature cycle		Within ±20%		Shall not exceed the initial requirements		Shall not exceed the initial requirements		–55°C to +20°C to +105°C 5 cycles (As per 4.21)
Resistance to soldering heat		Within ±20%		Shall not exceed 130% of the initial requirements		Shall not exceed the initial requirements		Reflow: 240°C, 10 seconds
Damp heat		+30% to –20%		Shall not exceed 150% of the initial requirements		Shall not exceed the initial requirements		40°C 90 to 95% RH 500 hours (As per 4.22)
Endurance I		Within ±20%		Shall not exceed 150% of the initial requirements		Shall not exceed the initial requirements		85°C Rated voltage application 1,000 hrs (As per 4.22)
Endurance II		Within ±20%		Shall not exceed 300% of the initial requirements		Shall not exceed the initial requirements		105°C Derated voltage application 1,000 hrs (As per 4.23)
Failure rate		λ_0 = 1%/1,000 hour						105°C Derated voltage application 1,000 hrs (As per 4.23)
Terminal strength		Visual: There shall be no evidence of mechanical damage						After board mounting, apply 4.9 N force in 2 directions
Permissible ripple current		According to individual catalog						at 100 kHz
Other		Conforms to IEC 60384-1						Conforms to IEC 60384-1

Reference: Derated voltage (85 to 105°C)

$$[U_T] = [U_R] - \frac{[U_R]-[U_C]}{20}(T-85)$$

$[U_T]$: Derated voltage at operating temperature
$[U_R]$: Rated voltage
$[U_C]$: Derated voltage at 105°C
T: Ambient temperature

PS/G Series

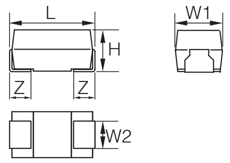
New Product

■ FEATURE

- **Lead-free type. In conformity to RoHs.**
- **Extreme low ESR (6mhom) and excellent noise absorption performance.**
- **High capacitance and ultra low ESR based upon our original Conductive Polymer technology.**
- **Same outer dimensions as those of conventional PS/L series.**

■ DIMENSIONS

[V, D Case]



(Unit: mm)

Case Code	L	W_1	W_2	H	Z
V	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.2	1.9 ± 0.1	1.3 ± 0.2
D	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.2	2.8 ± 0.2	1.3 ± 0.2

■ STANDARD C-V VALUE REFERENCE BY CASE CODE

UR: Rated voltage

U_R / μF		2.5 V 0E	
220	227	[V 9]	
330	337	V 9, [7]	D 9,7
470	477	[V 9, 7]	D 9,7,6
680	687		D 9,7

Numeral: ESR (m) at 100kHz

[ ]: Under development-under specification to be determined

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■ PART NUMBER SYSTEM

[Bulk]

PSG D 0E 477 M 7

- 7 — Special numbering for ESR (ex.7 means 7 m‰.)
- M — Capacitance tolerance (M: ±20%)
- 477 — Capacitance (in pF) (The first two digits represent significant figures. The third digit specifies number of zero to follow.)
- 0E — DC rated voltage in volts
- D — Case code
- PSG — PS/G Series

[Tape and Reel]

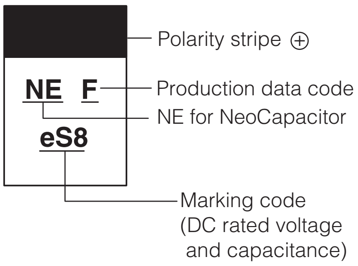
TE PSGD0E477M7 -12 R

- R — Packing orientation (R: cathode on the side of sprocket hole)
- -12 — Tape width (-12: 12 mm)
- PSGD0E477M7 — Part number of bulk
- TE — Tape and reel (TE: 180mm ϕ reel)

TL PSGD0E477M7 -12 R E

- E — Indicate 330mm ϕ reel
- TL — Tape and reel (TL: 330mm ϕ reel)

■ MARKINGS



[Rated voltage and capacitance]

UR: Rated voltage

μF		UR 2.5 (0E)
220	227	[eJ8]
330	337	eN8
470	477	eS8
680	687	eW8

[ ]: Under development

[Production date code]

Y \ M	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2003	a	b	c	d	e	f	g	h	j	k	l	m
2004	n	p	q	r	s	t	u	v	w	x	y	z
2005	A	B	C	D	E	F	G	H	J	K	L	M
2006	N	P	Q	R	S	T	U	V	W	X	Y	Z

Note: Production date code will resume beginning in 2007.

■ PERFORMANCE CHARACTERISTICS

Test Conditions: Conform to IEC 60384-1

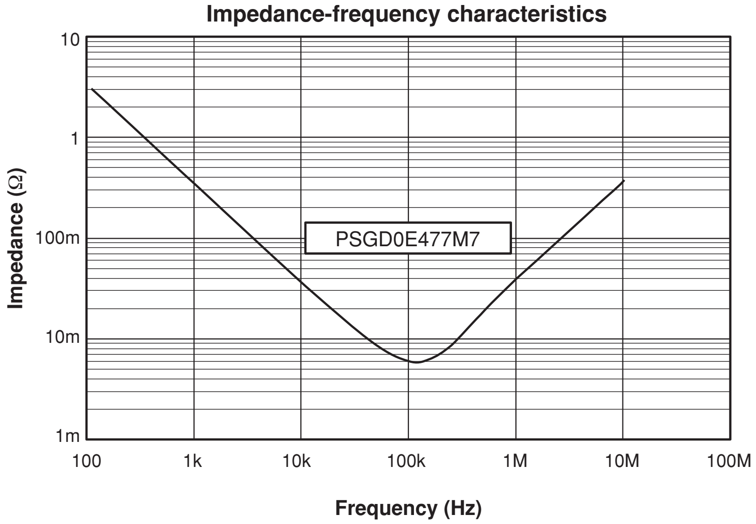
Item		Performance			Test Conditions (IEC 60384-1)
Operating temperature range		–55°C to +105°C			Derated voltage if 85°C is exceeded
Rated voltage		2.5V			at 85°C
Derated voltage		2V			at 105°C
Surge voltage		3.3V			at 85°C
Capacitance		330 μF to 680 μF			at 120 Hz (As per 4.7)
Capacitance tolerance		±20%			
Leakage current		Less than the value of 0.1C • V(μA) or 3 μA, whichever is greater			5 minutes after rated voltage application (As per 4.9)
Dissipation factor		According to individual catalog			at 120 Hz (As per 4.8)
Equivalent series resistance		According to individual catalog			at 100 kHz
		Capacitance change	DF	Leakage current	
Surge		Within ±20%	Shall not exceed the initial requirements	Shall not exceed the initial requirements	(As per 4.26)
Characteristics at high and low temperature	–55°C	From 0 to –20%	Shall not exceed the initial requirements	———	(As per 4.24)
	+105°C	From 0 to +50%	Shall not exceed 150% of the initial requirements	Shall not exceed 10 times of the initial requirements	
Temperature cycle		Within ±20%	Shall not exceed the initial requirements	Shall not exceed the initial requirements	–55°C to +20°C to +105°C 5 cycles (As per 4.21)
Resistance to soldering heat		Within ±20%	Shall not exceed 130% of the initial requirements	Shall not exceed the initial requirements	Reflow: 240°C, 10 seconds
Damp heat		From +30% to –20%	Shall not exceed 150% of the initial requirements	Shall not exceed the initial requirements	40°C 90 to 95% RH 500 hours (As per 4.22)
Endurance I		Within ±20%	Shall not exceed 150% of the initial requirements	Shall not exceed the initial requirements	85°C Rated voltage application 1,000 hrs (As per 4.22)
Endurance II		Within ±20%	Shall not exceed 300% of the initial requirements	Shall not exceed the initial requirements	105°C Derated voltage application 1,000 hrs (As per 4.23)
Failure rate		λ_0 = 1%/1,000 hour			105°C Derated voltage application 1,000 hrs (As per 4.23)
Terminal strength		Visual: There shall be no evidence of mechanical damage			After board mounting, apply 4.9 N force in 2 directions
Permissible ripple current		According to individual catalog			at 100 kHz
Other		Conforms to IEC 60384-1			Conforms to IEC 60384-1

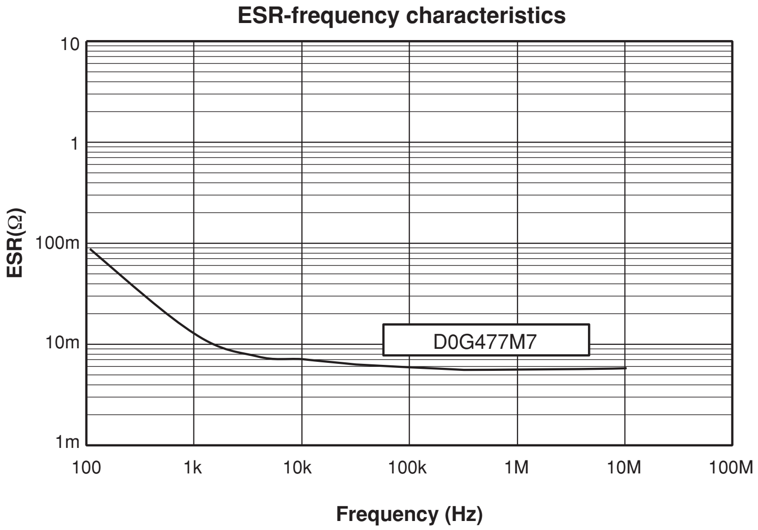
Reference: Derated voltage (85 to 105°C)

$$[U_T] = [U_R] - \frac{[U_R]-[U_C]}{20}(T-85)$$

$[U_T]$: Derated voltage at operating temperature
$[U_R]$: Rated voltage
$[U_C]$: Derated voltage at 105°C
T: Ambient temperature

■ **FREQUENCY CHARACTERISTICS (reference)**





3. Conductive Polymer Niobium Capacitors

NB/P Series

■ Overview

The NB/P series is the world's first conductive polymer capacitors with solid electrolyte to use niobium (Nb) as the anode electrode. We promoted the development of niobium powder materials based on manufacturing technologies nurtured by long years of tantalum capacitor manufacturing and cooperation with materials manufacturers. We then used an originally developed technology to overcome the thermal instability of the niobium oxide film, which had been the toughest problem to solve, and finally succeeded in commercializing the NB/P series

If the niobium powder materials are further improved and the production volume of the materials increase in the future, they will be superior to tantalum materials in terms of cost. As a result, it will be possible to produce conductive polymer niobium capacitors with a capacitance of 1.000 μF or more--a capacitance which commercial tantalum capacitors could not realize because of cost.

■ Features

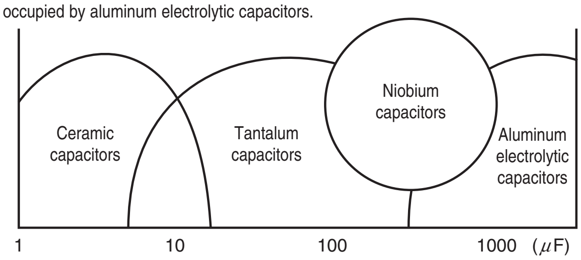
- The product supply is stable due to the employment of niobium as main material. Niobium reserves are presumed to be 100 times higher than those of tantalum.
- The structure and shape are the same as those of conventional chip tantalum capacitors.
  The performance is also comparable to that of chip tantalum capacitors.
- By using a conductive polymer as the electrolyte, low equivalent series voltage (ESR) characteristics are realized.

■ Applications

- Computers and PDAs (for high-speed microprocessor decoupling)
- High-performance game machines (for high-speed image processing)

Main target of niobium capacitors in capacitor market

The main target is the market for capacitors with a large capacity-100 pF or more-which is occupied by aluminum electrolytic capacitors.



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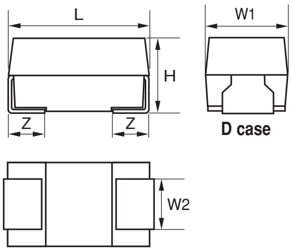
■ DIMENSIONS [mm]

[D case]



(Unit: mm)

Case Code	L	W_1	W_2	H	Z
D	7.3 ± 0.2	4.3 ± 0.2	2.4 ± 0.1	2.8 ± 0.2	1.3 ± 0.2

■ PRODUCT LIST AND MAIN SPECIFICATIONS

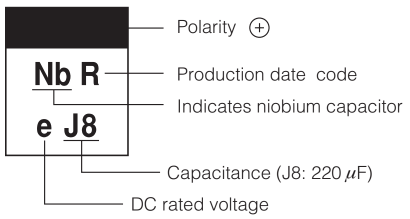
Rated Voltage	Nominal Capacitance	Case Code	Specifications		
			DF	Leakage current	ESR
2.5 V	220 μF	D	0.50 max	55 μA max	55 mΩ max

■ PRODUCT LIST AND MAIN SPECIFICATIONS

[Bulk] **NBP D 0E 227 M**

- M — Capacitance tolerance (M: ±20%)
- 227 — Capacitance (pF) (The first two digits represent significant figures. The third digit specifies the number of zeros to follow.)
- 0E — DC rated voltage code (0E: 2.5 V)
- D — Case code
- NBP — NB/P series

■ Marking



[Production date code]

Y \ M	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2003	a	b	c	d	e	f	g	h	j	k	l	m
2004	n	p	q	r	s	t	u	v	w	x	y	z
2005	A	B	C	D	E	F	G	H	J	K	L	M
2006	N	P	Q	R	S	T	U	V	W	X	Y	Z

Note: Production date code will repeat beginning in 2007.

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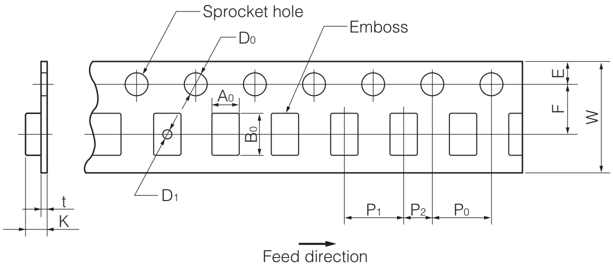
4. TAPE AND REEL SPECIFICATIONS

■ Plastic Tape Carrier



Unit: mm

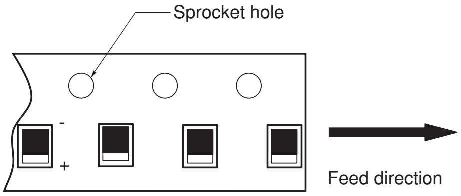
Case Code	$A_0 \pm 0.2$	$B_0 \pm 0.2$	$K \pm 0.2$
J	1.0	1.8	1.1
P	1.4	2.2	1.4
A2 (U)	1.9	3.5	1.4
A	1.9	3.5	1.9
B3	3.2	3.8	1.4
B2 (S)	3.3	3.8	2.1
C2	3.7	6.4	1.7
C	3.7	6.4	3.0
V	4.6	7.7	2.4
D	4.8	7.7	3.3

Unit: mm

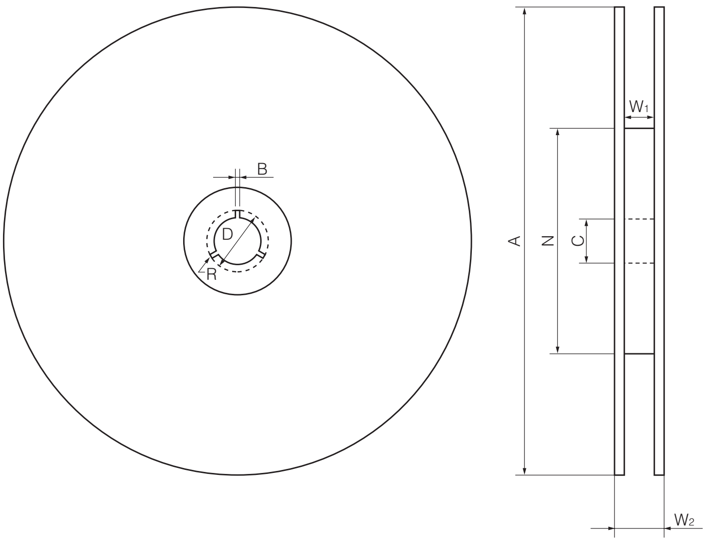
<table>
<tr><th>Case Code</th><th>$W \pm 0.3$</th><th>$F \pm 0.05$</th><th>$E \pm 0.1$</th><th>$P_1 \pm 0.1$</th><th>$P_2 \pm 0.05$</th><th>$P_0 \pm 0.1$</th><th>$D_0{}^{+0.1}_{0}$</th><th>D_1 min.</th><th>t</th></tr>
<tr><td>J</td><td rowspan="6">8</td><td rowspan="6">3.5</td><td rowspan="10">1.75</td><td rowspan="6">4</td><td rowspan="10">2</td><td rowspan="10">4</td><td rowspan="10">ϕ1.5</td><td>–</td><td rowspan="6">0.2</td></tr>
<tr><td>P</td><td>–</td></tr>
<tr><td>A2 (U)</td><td rowspan="4">ϕ1.0</td></tr>
<tr><td>A</td></tr>
<tr><td>B3 (W)</td></tr>
<tr><td>B2 (S)</td></tr>
<tr><td>C2</td><td rowspan="4">12</td><td rowspan="4">5.5</td><td rowspan="4">8</td><td rowspan="4">ϕ1.5</td><td rowspan="2">0.3</td></tr>
<tr><td>C</td></tr>
<tr><td>V</td><td>0.4</td></tr>
<tr><td>D</td><td>0.3</td></tr>
</table>

■ Packing Orientation

ex. R:Cathode on the side of sprocket hole



REEL



Unit: mm

Tape Width	A	N Min.	C ± 0.5	D	B ± 0.5	W_1	W_2 Max.	R
8 mm	$\phi180^{+0}_{-3}$	$\phi50$	$\phi13$	$\phi21 \pm 0.5$	2	9.0 ± 1.0	11.4 ± 1.0	1
12 mm						13.0 ± 1.0	15.4 ± 1.0	
8 mm	$\phi330 \pm 2$	$\phi80$	$\phi13$	$\phi21 \pm 1.0$	2	10.0 Max.	14.5 Max.	1
12 mm						14.0 Max.	18.5 Max.	

Case Code	$\phi180$ Reel	$\phi330$ Reel
J	4000	–
P	3000	–
A2 (U)	3000	10000
A	2000	9000
B3 (W)	3000	10000
B2 (S)	2000	5000
C2	1000	4000
V	1000	3000
C, D	500	2500

[Quantity Per Reel]

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While NEC TOKIN Corporation has been making a continuous effort to enhance the reliability of its electronic components, the possibility of defects cannot be eliminated entirely. To minimize risks of damage or injury to persons or property arising from a defect in an NEC TOKIN electronic component, customers must incorporate sufficient safety measures in its design, such as redundancy, fire-containment, and anti-failure features. NEC TOKIN devices are classified into the following three quality grades:

"Standard," "Special," and "Specific." The Specific quality grade applies only to devices developed based on a customer-designated quality assurance program for a specific application. The recommended applications of a device depend on its quality grade, as indicated below. Customers must check the quality grade of each device before using it in a particular application.

- Standard: Computers, office equipment, communications equipment, test and measurement equipment, audio and visual equipment, home electronic appliances, machine tools, personal electronic equipment, and industrial robots
- Special: Transportation equipment (automobiles, trains, ships, etc.), traffic control systems, anti-disaster systems, anti-crime systems, safety equipment, and medical equipment (not specifically designed for life support)
- Specific: Aircraft, aerospace equipment, submersible repeaters, nuclear reactor control systems, life support systems, or medical equipment for life support, etc.

The quality grade of NEC TOKIN devices is "Standard" unless otherwise specified in NEC TOKIN's data sheets or data books. If customers intend to use NEC TOKIN devices for applications other than those specified for Standard quality grade, they should contact an NEC TOKIN sales representative in advance.

(Note)

(1) "NEC TOKIN" as used in this statement means NEC TOKIN Corporation and also includes its majority-owned subsidiaries.

(2) "NEC TOKIN electronic component products" means any electronic component product developed or manufactured by or for NEC TOKIN (as defined above).